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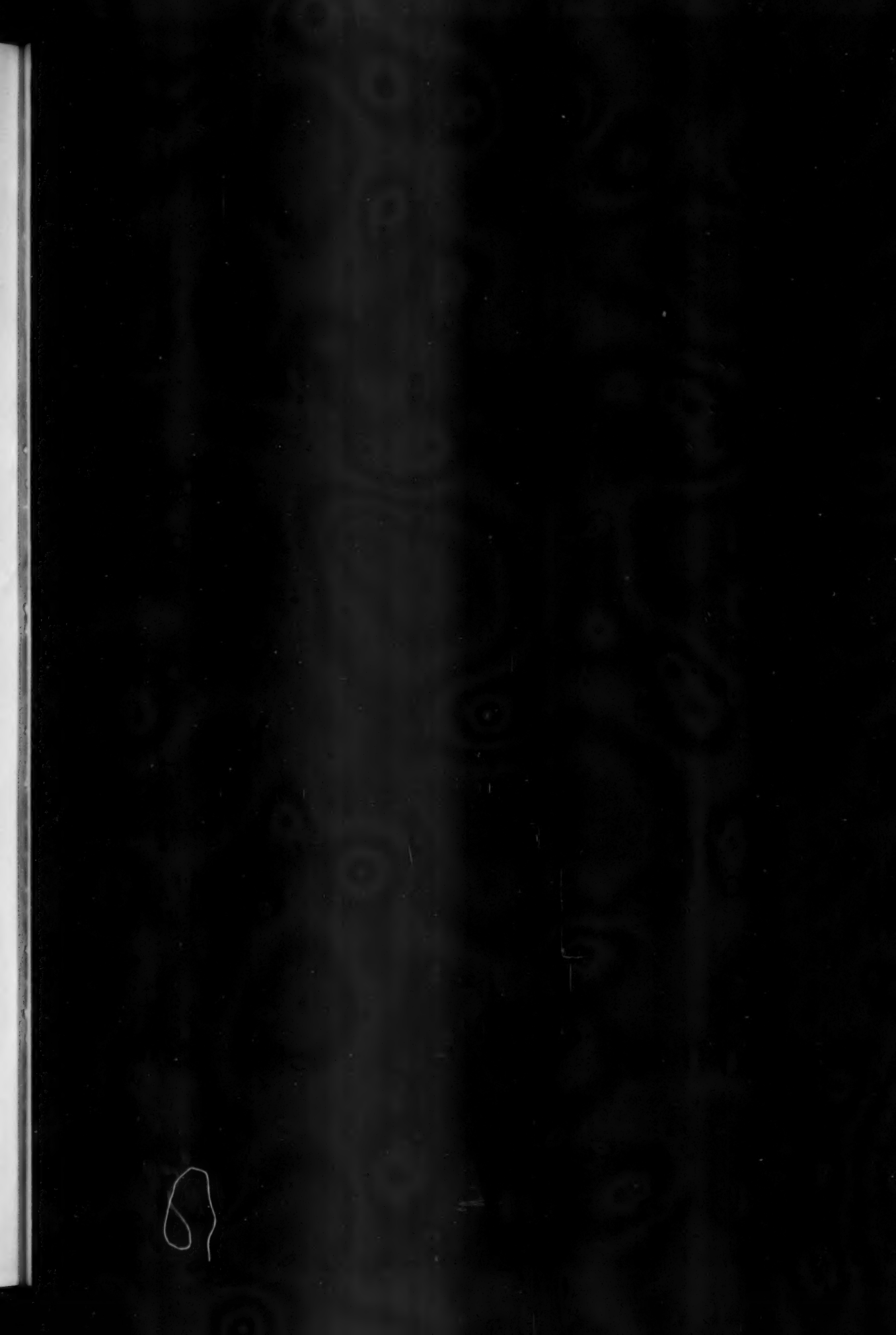

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The Cigarette Beetle as a Pest of Cottonseed Meal

E. A. Back, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine*

The warehousing of cottonseed meal brings its own insect problem if storage is protracted. The principal pest involved is the cigarette beetle, *Lasioderma serricorne* (F.). While this insect develops to tremendous numbers in cottonseed meal, it can hardly be said to affect adversely more than a small portion of the meal in storage when one considers the value of the meal for feeding and fertilizer purposes. The infestation is limited in commercially valuable meal very largely to the outer 2 to 3 inches of the commodity, whether this be stored in sacks or in bulk.

The real losses caused by *Lasioderma* attack are associated with the destruction of the sacks by the larvae, fig. 1. This necessitates charges for new sacks, for labor involved in regrinding and resacking just previous to sale, for fumigations and for the costs associated with the return of infested materials, acceptance of which has been refused at destination by the consignee, or for discounts to influence the consignee to accept what he considers, or pretends to consider, an inferior shipment. There is also the loss of sales due to a consignor's reputation for possessing infested stocks, to the well-grounded fear that taking infested meal into an establishment may contaminate other commodities not then infested and to the repeatedly expressed but needless fear that feeding "weevily meal" to cattle will in some manner affect them adversely (Doane 1925).

It would seem that *Lasioderma* infestations in cottonseed meal warehouses in the southern part of the United States must be expected if the product does not move normally. Abnormal conditions during 1934 and 1935 brought about by the reductions in cotton acreage and in numbers of cattle and hogs, and an increase in certain imports, greatly curtailed the usual markets for cottonseed meal as a livestock feed and as a fertilizer. As a result stocks were held for long periods which normally would have been disposed of so promptly that most of the crop of cottonseed in the form of cakes or meal would be marketed without noticeable infestation.

Where no remedial measures are taken, the insects are present at all times in and about meal establishments, not only in the marketable product but also in meal siftings, broken seeds and similar debris beneath floorings, on framework, dumps, etc. New stock becomes infested by spread from old stocks, and the cycle of infestation is easily maintained. Probably the only meal sold that is entirely free of *Lasioderma* is that ground after cold weather stops insect migrations and that sold before warm weather in the spring permits the flight of adults. Some firms holding meal ground from the 1933 crop of cottonseed found it badly infested during the August–October period of 1934, while others in 1935 had the same experience with the meal ground from the 1934 seed.

Distribution of *Lasioderma* in Sacked Meal.—All examinations of sacked cottonseed meal indicate that the *Lasioderma* population is heaviest in the outer 2 or 3 inches directly beneath the sacking. Table 1 gives actual counts of insects sifted from pint samples taken from a 100-pound sack. From the top sack of a tier 12 sacks high, the sacking over the exposed top surface was cut away and samples were taken, representing as nearly as possible the condition existing at the various inch levels in the central portion of the sack, sample 1 being the uppermost inch exposed to the air and sample 11 the bottom inch of material above the lower side of the sack, which in turn was resting on the sack beneath.

It will be noted that in the pint sample

immediately beneath the jute cover of the bag there was a total of 6,363 *Lasioderma* as compared with 1,754, 255, 140, 23, 5, 11, 2, 2, 0 and 1 in each succeeding inch level. It is difficult to secure samples by this free-hand method of sampling, and it is possible that some contamination of samples 5 to 11 occurred during the sampling process. The insects were active and the meal was very friable.

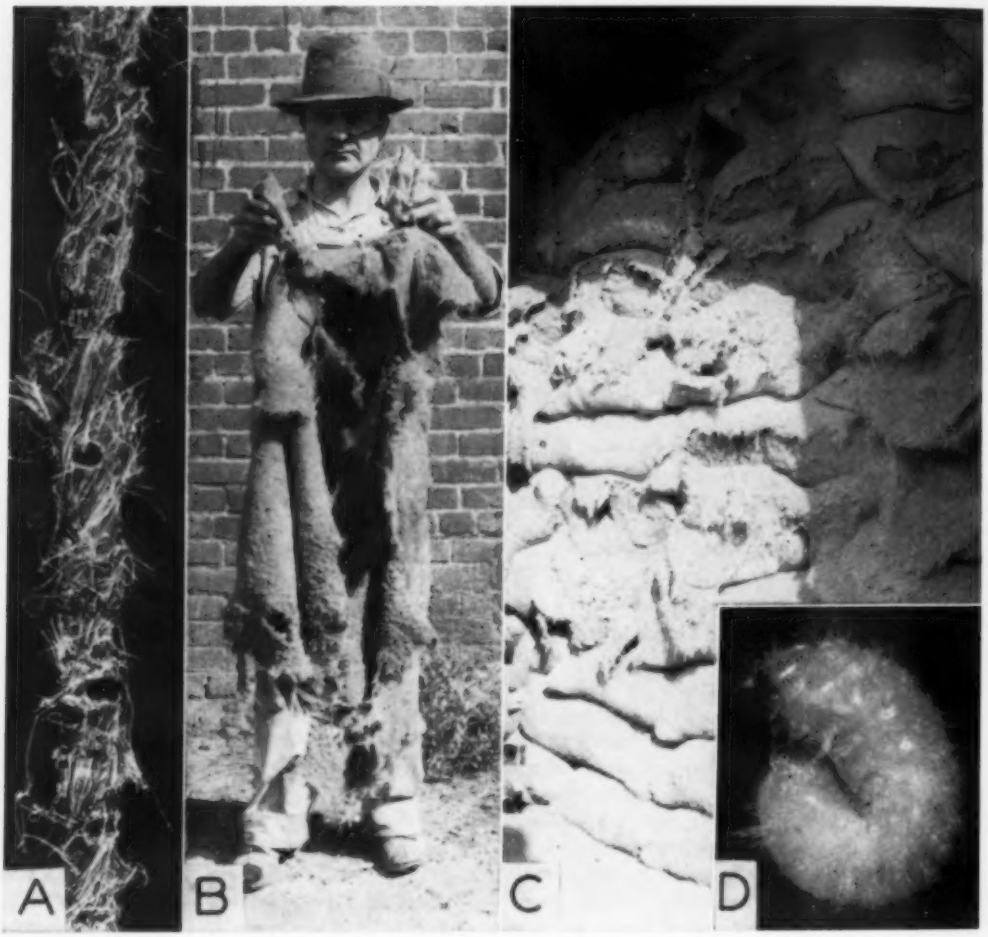

FIG. 1.—Injury by larvae of cigarette beetle to 8-ounce jute sacks each containing 100 pounds of cottonseed meal: *A*, single strand of sack, magnified three times, showing cutting of fibers by larvae; *B*, workman holding damaged sack, all that was left in his hands when he attempted to lift badly infested sack of meal; *C*, breaking of sacks caused by weight of man's body sliding down face of tier; *D*, larva of cigarette beetle magnified 10 times.

Table 2 presents other data bearing on distribution of infestation within sacks, obtained from another warehouse in August, 1934, from sacked meal ground not later than December from the 1933 seed crop. The infestation not being so heavy, there appeared to be less penetration. The samples were taken with a bulk grain probe thrust lengthwise of the 100-pound sacks through the center (*c*), along the left side (*l*), along the right side (*r*), or in the center at the lowest level (*u*). Owing to the difficulties in probing some of the sacks and the amount of material adhering to the sacks, six samples were taken from some bags and five from others. The chambers of the probe were each 3½ inches long by 1 inch deep and were spaced 3 inches apart. One should study the data of table 2 in connection with the diagram of fig. 2, showing the location of each sack. Sacks *a*, *b*, *d*, *e*, *h* and *g* have one end exposed on the aisle

Table 1.—Distribution of *Lasioderma serricorne, Tribolium confusum* and *Tenebroides mauritanicus* in a 100-pound sack of cottonseed meal.

SAMPLE	*Lasioderma serricorne*				*Tribolium confusum*				*Tenebroides mauritanicus*
	Adults	Larvae	Pupae	Total Forms	Adults	Larvae	Pupae	Total Forms	
1	756	5,231	376	6,363	5	7	0	12	4
2	46	1,627	81	1,754	4	6	1	11	2
3	8	240	7	255	—	—	—	10	0
4	5	131	4	140	1	4	0	5	0
5	0	22	1	23	2	2	0	4	0
6	0	3	2	5	1	3	0	4	0
7	1	10	0	11	0	3	0	3	1
8	0	2	0	2	1	2	1	4	0
9	0	2	0	2	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0
11	1	0	0	1	1	0	0	1	0

or passageway between tiers of sacks. Sacks *b*, *d* and *g* are exposed also along their right sides to an air space between the tier and the wall of the warehouse. Sacks *c*, *f* and *i* are in the center of the mass of sacks composing the "bay" and at the levels above the floor indicated; thus, $c_{(18)}$, $f_{(14)}$, $i_{(10)}$. The data for all center-of-sack probes and all probes in the center of the lowest level of the sacks indicate that the *Lasioderma* population is within the meal of the first sample. Data from the probes along the extreme right or extreme left of the sacks indicate an abundance of insects in the outer portion or a scarcity of insects, according to whether the sack surface is exposed to an air space or pressed against an adjoining sack. The left probe through *a* indicates the condition where the sacks are tightly appressed; the left probe through *e* indicates less tight stacking of sacks. The data from *c*, *f* and *i* indicate that *Lasioderma* adults penetrate to the center of storage piles no more bulky than the one under consideration and start considerable infestation.

DISTRIBUTION OF *LASIODERMA* IN BULK MEAL.—In determining the distribution of insects in bulk meal, samples were taken at the surface and at 6 and 12 inches below the surface. Samples taken from each level were well mixed and 1 pint was taken for examination, with the result shown in table 3. For some reason the sample from the surface does not seem representative of the relative abundance of the life stages of *Lasioderma* as found elsewhere in the warehouse at that time. The relatively large proportion of adults in the meal at the surface of the bulk pile is doubtless due to the fact that the pile of meal was near a skylight, to which adults have flown and from which many had dropped to the floor and crawled

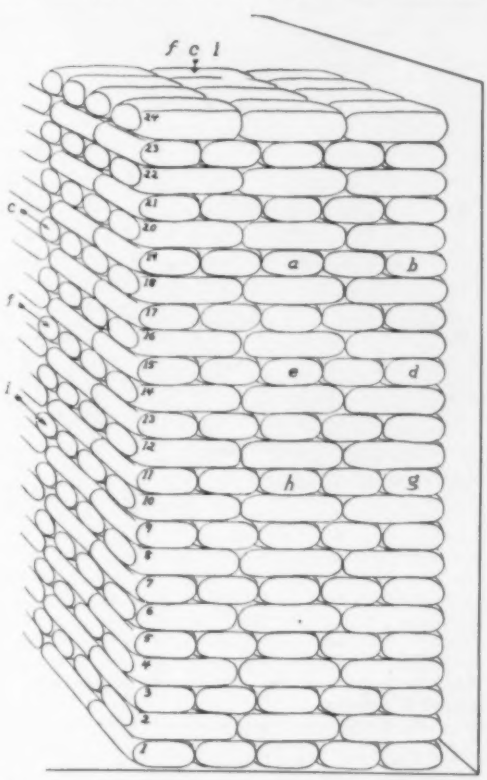

FIG. 2.—Diagrammatic sketch of one-half of 100-pound sacks of cotton seed meal in which were located the sacks from which samples were taken for data recorded in table 2. Sacks *a*, *b*, *e*, *d*, *h* and *g* were sampled from the aisle they face, but to get at sacks *f*, *c* and *i* at the eighteenth, fourteenth and tenth sack levels respectively the pile had to be torn down, with the resulting breakage shown in fig. 7.

Table 2.—Distribution of *Lasioderma* in 100-pound sacks and numbers killed by hydrocyanic acid gas fumigation.

Bag and Probe	Sample	*Lasioderma*			Bag and Probe	Sample	*Lasioderma*		
		Alive	Dead	Total			Alive	Dead	Total
a_l	1	4	235	239	h_c	1	4	111	115
	2	0	2	2		2	0	0	0
	3	0	0	0		3	0	0	0
	4	0	0	0		4	0	0	0
	5	0	0	0		5	0	0	0
a_c	1	1	109	110	g_c	1	3	231	234
	2	0	0	0		2	0	0	0
	3	0	0	0		3	0	0	0
	4	0	0	0		4	0	0	0
	5	0	0	0		5	0	0	0
	6	0	0	0		6	0	0	0
a_u	1	3	362	365	c_c	1	2	10	12
	2	0	3	3		2	0	0	0
	3	0	0	0		3	0	0	0
	4	0	0	0		4	0	0	0
	5	0	0	0		5	0	0	0
	6	0	0	0		6	0	0	0
b_u	1	1	162	163	c_l	1	63	11	74
	2	0	0	0		2	0	0	0
	3	0	0	0		3	0	0	0
	4	0	0	0		4	0	0	0
	5	0	0	0		5	0	0	0
	6	0	0	0		6	0	0	0
b_r	1	2	28	30	f_c	1	6	6	12
	2	0	4	4		2	0	0	0
	3	0	11	11		3	0	0	0
	4	0	42	42		4	0	0	0
	5	0	71	71		5	0	0	0
						6	0	0	0
e_l	1	10	42	52	i_l	1	104	8	112
	2	0	0	0		2	7	3	10
	3	1	7	8		3	0	0	0
	4	2	19	21		4	0	0	0
	5	3	6	9		5	0	0	0
						6	0	0	0
d_r	1	—	—	—	i_c	1	65	9	74
	2	1	62	63		2	2	0	2
	3	1	21	21		3	0	0	0
	4	2	174	176		4	0	0	0
	5	1	31	32		5	0	0	0
	6	0	0	56		6	15	0	15

Table 3.—Distribution, in October, 1935, of *Lasioderma serricorne, Tribolium confusum, Tenebroides mauritanicus, Attagenus piceus* and *Ephestia* in bulk pile of cottonseed meal *in situ* about 2 months.

Level at Which Samples Taken	*Lasioderma serricorne*				*Tribolium confusum*				*Tenebroides mauritanicus*	*Attagenus piceus*	*Ephestia cautella*
	Adults	Larvae	Pupae	Total	Adults	Larvae	Pupae	Total			
Surface	10,800	58	0	10,858	114	49	13	176	7	3	2
6 inches below surface	1	3	0	4	1	0	2	3	0	0	0
12 inches below surface	0	2	0	2	0	0	0	0	0	0	0

into the meal nearby for oviposition and hiding during the day.

LASIODERMA ATTACHED TO SACKS.—As the *Lasioderma* larvae mature, they move as close to the sack covering as possible, in order to construct their pupal chambers, fig. 3. When constructed with no extraneous matter, the cocoons are white and filmy, but in cottonseed meal the larvae build into the walls of the chamber so many particles of meal and seed hulls that the resulting cocoon resembles more a bit of hull than a hollow chamber sheltering an insect. A series of these pupal cocoons may be attached to a single sack fiber. In fig. 3*A* is shown the solid mass of cocoons which one finds attached to the inside of a well-infested sack when it is opened carefully. This layer of cocoons may be continuous and normally is about one-fourth inch in depth, although masses of cocoons one-half to three-fourths inch thick have been found. It seems probable that pupal chambers are repeatedly occupied by larvae moving up to the sack surface, one cocoon cavity, with repairs, being used over and over by a succession of maturing grubs. A series of these pupal chambers after the sacking has been carefully removed, may be seen (enlarged 5 times) in fig. 3*B*.

This layer of pupal cells is rich in insect life. *Lasioderma* counted on 4 square inches of sacking showed an average per square inch of 96 individuals in adhering chambers, and an average of 23 others that were more or less free moving and easily dislodged. This is the population that parts with the meal when its sacking is cut and carefully turned back. In the outer 2 inches of the free meal, along with those found in the encrustation of pupal cells attached to the sack, there were in one instance, which seemed typical of exposed sack surface, a total of 16,179 *Lasioderma* forms represented by 72 square inches of sack surface, an average of 224.7 specimens per square inch.

INSECTS IN REFUSE MEAL.—By refuse meal is meant the fine siftings of meal from sacks caused by insect activity within the sacks, fig. 4*B*, as meal dust settled on exposed surface timbers, lodged in floor cracks and accumulated under floors and within wall spaces and even on dumps exposed to the weather. From a representative pint sample taken from the floor along a tier of sacks in one establishment there were counted 5,974 adults, 519 larvae and 402 pupae of *Lasioderma*. These accumulations of meal dust are often so badly infested that they are stuck to the floors by the cocoons.

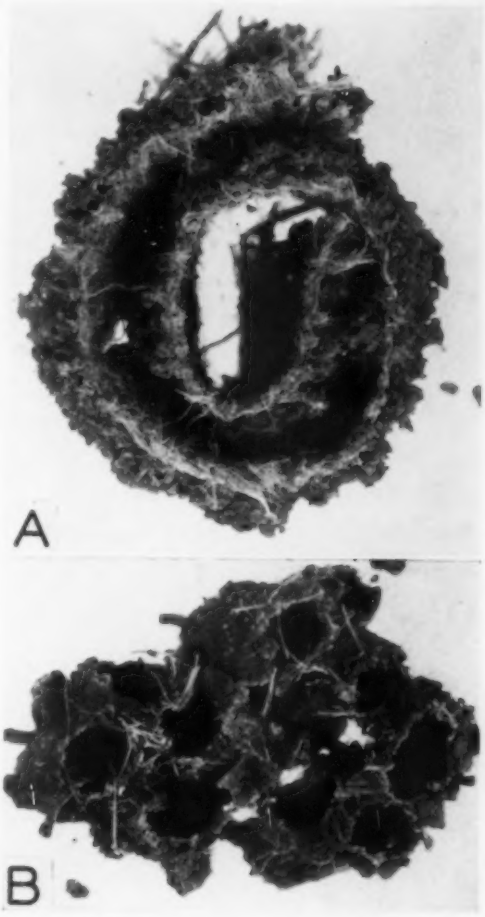

FIG. 3.—Pupal chambers of cigarette beetle attached to under surface of 100-pound sacks of cottonseed meal: *A*, shown natural size attached to surface of sack; *B*, outer surfaces of cells, magnified five times, after adult emergence and after removal of sacking.

DESTRUCTION OF SACKS.—Cottonseed meal is usually marketed in 100-pound jute sacks. Most of the cutting of sacks observed by the writer took place in 8-ounce bags. In fig. 3*B* is shown a group of pupal chambers from the outer edge of which the sack has been carefully peeled. As the larva constructs its cell, it usually attaches it to the sack if possible and, knowing by instinct that the adult beetle must escape to the outside if it is to ac-

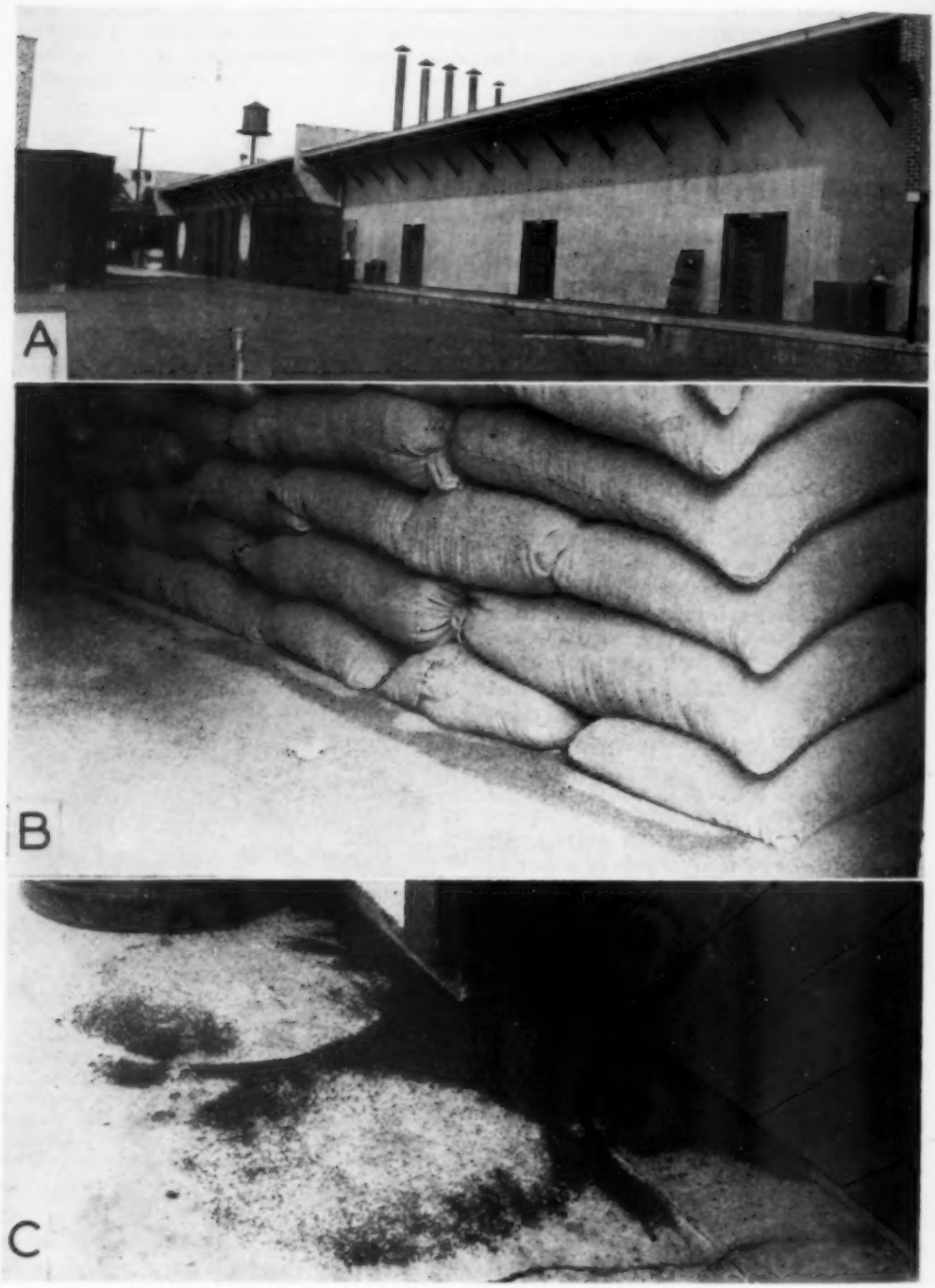

FIG. 4.—In and about cottonseed meal warehouse: *A*, exterior view of excellent storage warehouse; *B*, sacks of cottonseed meal arranged as indicated in fig. 2 and showing the whitish piles of refuse meals on floor close to sacks and further from sacks on floor the dark line composed of dead cigarette beetles; *C*, adult beetles emerging from warehouse through door cracks and dying on cement loading platform (note imprint of two barrels removed by photographer).

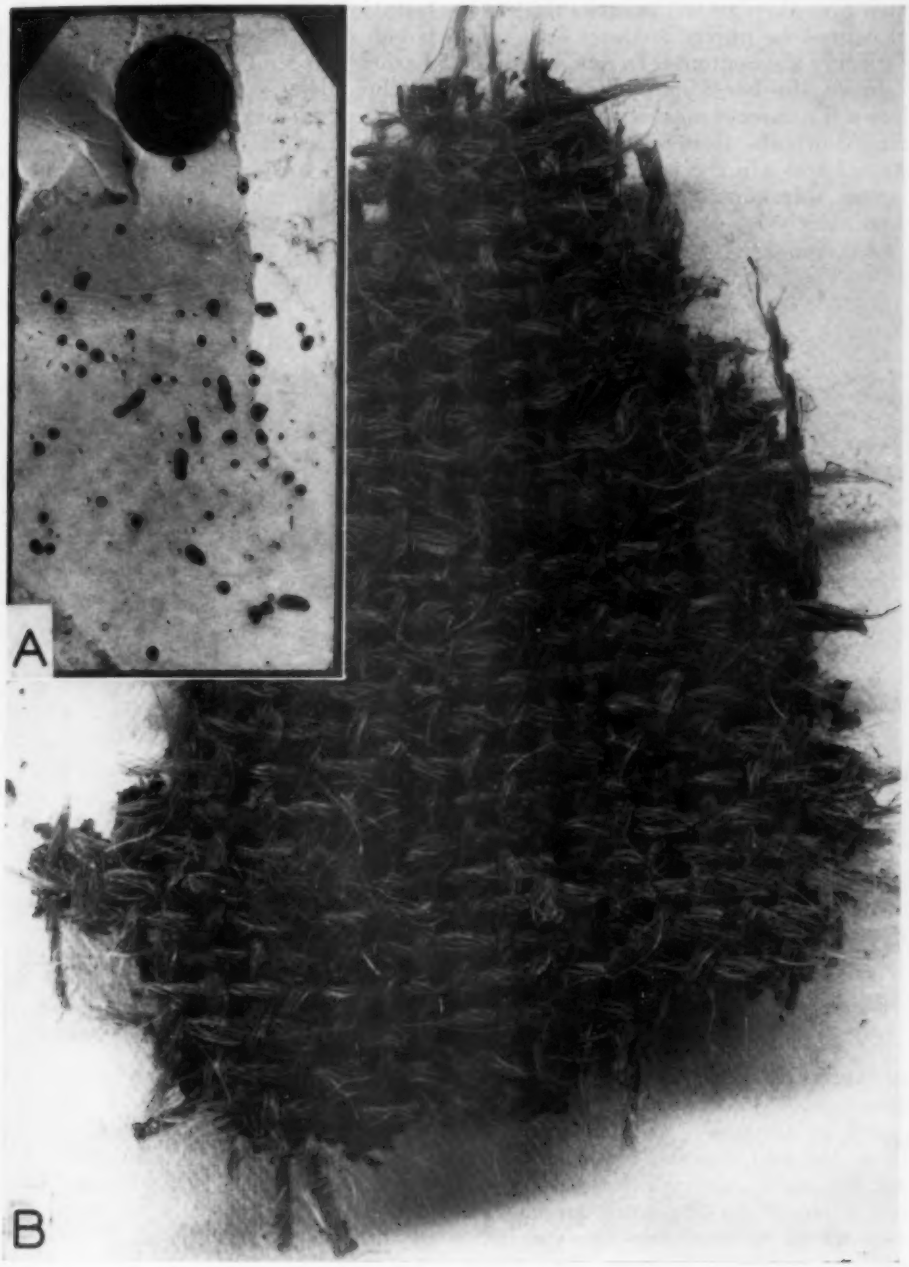

FIG. 5.—*A*, holes cut by larvae in label closely applied to sack filled with infested meal (natural size); *B*, exterior view of sacking from badly infested bag (magnified two times) torn from sack by hand and showing general appearance resulting from emergence of large number of adult cigarette beetles.

complish best its purpose in life, the larva eats the fiber of the sack, or of labels pressed against the sacks, before it finally completes the filmy end of the cocoon. This cutting of the sack fibers or label is indicated in figs. 1 and 5. While many beetles emerge from the sacks through the interstices of the sack weave, the repeated emergence of others whose cocoons have been built against the fiber itself results

in such a weakening of the sacks that the meal cannot be moved without breaking and spilling the contents. In figs. 1 and 5*B* are shown the breaking sacks. In fig. 7 is shown the mass of meal that occurred in tearing down the tiers of fig. 2 to get at sacks *c*, *f* and *i* in the middle of the bay. In some warehouses the sacks can be broken merely by drawing the forefinger across them.

BREAKING OF SACKS CONFINED TO AREAS OF INFESTATION.—The breaking of sacks in handling is confined to those portions badly infested with *Lasioderma*. For instance, sack *a* broke only on the end exposed to the aisle, sack *b* broke not only on the end exposed to the aisle but along the right edge exposed to the air space adjacent to the wall. In one instance where a large tonnage was torn down and put into bulk, a good many sound sacks were found within the mass of stacked sacks, but these were in the interior and carried little infestation. Those portions of the sacks that are closely pressed together in stacking are unaffected by *Lasioderma* and do not break. There is considerable variation in the closeness with which the sacks are stacked. The tighter the packing and the larger the piles of sacks the less the infestation. The larger the air spaces between sacks the more easily do the adult *Lasioderma* find their way to the center of the piles. Note that considerable infestation existed during August in sacks *c*, *f* and *i* of fig. 2 and table 2. These infestations are far more important from the control standpoint than from that of injury to the meal.

FLYING ADULTS.—*Lasioderma* adults, fig. 6 insert, in the form of brown beetles fly readily, particularly to the skylights of the warehouse and to the open doors.

FIG. 6.—View in cottonseed meal warehouse heavily infested with cigarette beetle. Darkened areas on floor indicate countless dead beetles. Insert, adult cigarette beetles (magnified three times).

This flight is confined largely to late afternoon on bright days and to dull cloudy days. At such times so many adults are on the wing in the warehouses and about loading platforms that life may be made miserable for those who work or live within the neighborhood. The beetles do not bite, but get into the hair and beneath the clothing. They are found crawling over the outside of the warehouse in large numbers, and there is much passing to and fro through open doors, windows and cracks. During the day the beetles crawl into bulk meal and between sacks, or rest quietly on the outside of exposed sacks. Often the sacks appear darkened. The beetles may encrust rafters and other woodwork, particularly near skylights

and doors, and crowd the cracks in the timbers. They drop from the sacks in numbers to form windrows on the floor, figs. 4*B* and 6 along the tiers. Beneath one skylight the writer scooped up in less than 1 minute over 1½ gallons of beetles, estimated to contain 1,531,250 specimens. Sometimes when they gain access to the exterior of the warehouse through some slight opening, as about a door, fig. 4*C*, they die on the loading platform and can be scooped up in large quantities. It is difficult to conceive of the tremendous numbers of adult forms that develop even when the meal is only slightly damaged. These flying beetles invade residences in the vicinity of the meal establishments, usually for a limited number of days during the height of a flight, and cause no end of annoyance by disturbing the sleep of young children and ruffling the dispositions of adults, in addition to contaminating food supplies.

PARASITES.—A very common parasite in all cottonseed meal warehouses infested with *Lasioderma serricorne* is *Aplastomorpha calandrae* Howard. In October 1934, 21, 7 and 51 specimens of this parasite were found in the larval, pupal and adult stages along with 86, 54 and 332 *Lasioderma* specimens, respectively, attached to a total of 4 square inches of sacking. Parasitization is naturally heaviest just beneath the sacking in the pupal chambers. Beneath the sacking in the loose meal only 27 *Aplastomorpha* were found in a count of 3,554 *Lasioderma* specimens. Only the parasitic forms free from the bodies of their host insect were counted.

The *Aplastomorpha* adults seem to be attracted to the light, as are the *Lasioderma* adults. Beneath certain skylights and over sacks immediately surrounding such space the *Aplastomorpha* adults were so abundant among *Lasioderma* adults that their wings glistened in the reflected light, emphasizing their tremendous numbers. Unfortunately, they were not active enough to prevent the sacks from being destroyed by *Lasioderma* larvae.

OTHER INSECTS INVOLVED.—No attempt was made to study insects other than *Lasioderma serricorne*. In places large numbers of mealworms—*Tenebrio molitor* L., *T. obscurus* F., the cadelle *Tenebroides mauritanicus* (L.), *Tribolium confusum* Duv., *Ephestia cautella* (Walk.) and *Plodia interpunctella* (Hbn.)—were found. Of these, *T. confusum* was the most generally associated with *Lasioderma* in the sacked material, while in meal on the floor there were also *T. mauritanicus* and *Trogoderma tarsale* Melsh. In one warehouse in August, 1934, very few *T. confusum* specimens were found, the infestation being almost a pure culture of *Lasioderma*. But in the October, 1935, examinations in another storage about 100 *T. confusum* specimens were found to about 7,000 *Lasioderma* in refuse meal. In table 1 is recorded the relatively small number of *Tribolium* and *Tenebroides* found in a heavily infested sack of meal. Ordinarily, even when *Lasioderma* is abundant, other insect pests are of little importance in affecting the cottonseed meal. Sometimes *T. mauritanicus* fills sacking full of characteristic cuts, but this was not observed often. At the edges of bulk piles in depressions in the meal there are sometimes noticeable accumulations of the cast larval skins of *Tenebrio* spp. All storage pests are likely to be found

FIG. 7.—When sacks of cottonseed meal, indicated in fig. 2, were moved by workers they broke, throwing the meal into a common mass as indicated.

upon extended search, but only *Lasioderma* and possibly, under protracted periods of storage, *Tribolium* spp. are of importance.

FUMIGATION.—When sacked cottonseed meal has become badly infested, no general warehouse fumigation is likely to destroy all the insects. The warehouse shown in fig. 4*A*, was fumigated during hot weather in August, 1934, with hydrocyanic acid gas, barrel method, 1 pound of sodium cyanide per 1,000 cubic feet of the total 193,800 cubic feet of space involved. The sacks were in tiers mostly 24 sacks high, and about 2,500 tons of meal were in the warehouse. This warehouse had a concrete floor with walls and roof of galvanized iron applied to a wooden frame, and was the best warehouse used for meal storage in which the writer has experimented. The counts made after the fumigation, some of which are recorded in table 2, indicate that only about 87 per cent of the insects in the entire bulks of meal were killed, but, upon elimination of the insects which are present in smaller numbers in the interior of the piles of sacks to which the fumigant did not penetrate readily, the percentage of kill rose to about 98 per cent. This particular fumigation was followed by a second about 2 weeks later, in which only half a pound of cyanide was used per 1,000 cubic feet of space. The owners claimed that these two fumigations satisfactorily controlled the *Lasioderma* for the season.

In another warehouse, of loose construction, fumigation with hydrocyanic acid gas at the rate of 1 pound of sodium cyanide per 1,000 cubic feet of space seemed to do no more than kill the adult *Lasioderma* crawling over the outside of the sacks.

CONTROL RECOMMENDATIONS.—If cottonseed meal warehouses are too loosely constructed for effective fumigation, they should be tightened, at least the portions used for storing stock. Sacked meal in tight storage can well be protected if fumigated early in the season after insect activity is first observed. As the eggs hatch in warm weather in 6 to 10 days, the larvae become fully grown in 30 to 50 days, and the pupal stage required about 6 to 10 days, the entire life cycle of the cigarette beetle from the time the egg is laid until the adult emerges is only 42 to 70 days. Recognizing this, and the fact that the females may lay as many as 200 eggs each, one can appreciate the practical value of starting control applications early when experience warns that trouble will come with storage throughout the summer. If fumigation is conducted in late spring or early summer, the percentage of insects escaping will represent numerically few specimens as compared with the same percentage later in the season. As sacks cost from 5½ to 7 cents each, the saving in sacks alone by early fumigation is considerably over and above the cost of fumigation. One fumigation with 1 pound of sodium cyanide or its equivalent for each 1,000 cubic feet of space has proved very satisfactory. Two fumigations with 10 ounces per 1,000 cubic feet spaced 2 or 3 weeks apart can be made effective. Most cottonseed warehouses are too loosely constructed to maintain a proper concentration of a heavier-than-air fumigant unless the liquid fumigant is injected within the interior of the sacks.

If owners fear criticism of their product at point of destination because hot weather or bright sun causes insects within the product to crawl over the sacks, and their establishments are too loosely constructed for fumigation, they can arrange to fumigate carload lots in a special constructed room located near the shipping platform. Such carload lot fumigations may be worth their cost from the standpoint of allaying suspicion. As already stated, cottonseed meal may be considerably infested just beneath the sacking and yet be excellent for animal and poultry feed.

Infested meal can be reground just prior to resacking and shipment and practically all the insects killed, with the possible exception of the eggs. No examinations were made to determine the effect on eggs.

If compartments used for storing meal in bulk are furnished with cement floors and tight walls, the meal can be satisfactorily fumigated beneath tarpaulins with a heavier-than-air fumigant and kept relatively free from insects throughout the season.

Suction light traps might prove useful in checking infestations, as it has been demonstrated by the investigation of the Bureau of Entomology and Plant Quaran-

tine in tobacco warehouses that tremendous numbers of *Lasioderma* adults can be captured by a trap devised for this purpose.—1-9-39.

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Insect Collections and Rearings on Castor Bean Plants, With Especial Reference to Grasshoppers*†

ROGER C. SMITH, *Kansas Agricultural Experiment Station, Manhattan*

Publicity in magazines and newspapers declaring that crops could be protected from injurious insects by border or strip plantings of the castor bean, *Ricinus communis* L., stimulated interest in the poisonous and supposedly protective powers of this plant (Bear 1938). This publicity did not originate from an entomological source, but the idea was accepted by the general public as indicating a new and better method of grasshopper control. Correspondence on the subject in this and some other states increased to the point that mimeographed circular letters were prepared. The seed houses were early sold out of castor beans. Many farmers and gardeners throughout the great plains area planted the beans in the hope of insect control.

Published work bearing on the subject gave little or no hope that castor bean plants would kill any of the common farm pests or that the plants had any crop protecting value. But the old belief that "a castor bean plant in a garden will keep out moles" made the insect repelling and poisoning claims appear reasonable. The above facts indicated that it was desirable to make observations on experimental plantings to ascertain the normal insect feeders on castor beans and to study the supposed crop protective value of the plants. This report is based on these observations for one season, 1938. No further work on the subject is contemplated.

REVIEW OF THE LITERATURE.—Most of the writing on castor bean insects has originated in the eastern hemisphere. Among the more nearly complete lists of castor bean insects should be mentioned the following: Bedford (1930) for Khartoum; Grünwald (1930) for Germany; Wolcott (1918) for Ceylon; and Mamonov (1930) for the Caucasus. These and other reports indicate that castor bean plants have a few insect pests which may do some injury, especially to young plants.

DeOng (1918) summarized the insect pests of the castor bean in California and pointed out that it served as a host plant for many common insects, such as cutworms and a species of *Blapstinus* which feeds on the stems of young plants and attacks tomatoes in the same way. He reported *Laphygma flavimaculata* Harvey (=*L. exigua* Hbn.) as feeding on the leaves.

Watson (1919) reported a list of castor bean insects for the previous year in Florida, among which were cutworms, three species of armyworms: the southern, *Prodenia eridania* (Cramer), the yellow-striped armyworm, *Prodenia ornithogalli* Guen., and the fall armyworm, *Laphygma frugiperda* (S. & A.), for which dusting the plants with lead arsenate was the remedy applied; bean leafhoppers, *Empoasca fabae* (Harr.), among others attacked the leaves; the cotton lacebug, *Corythucha gossypii* (F.), the leaves; the pink corn worm, *Pyroderces rileyi* Wlsm., a scavenger, the spikes; the corn ear worm, *Heliothis obsoleta* (F.), attacked the pods; and the southern green stinkbug, *Nezara viridula* (L.) also the pods. Gibson (1919) reported species of Tingids, *Corythaica* and *Dolichocysta*, on *Ricinus communis*. Metzger (1933) stated that cage experiments showed that castor bean foliage was practically non-toxic to Japanese beetles. Tests proved that this plant was of little or no value as a trap plant under field conditions. Heavy infestations occurred

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on it when the beetles were plentiful after the favorite food plants had been severely injured.

There are indications or claims in the literature that castor bean plants may have crop protective value. Gobbato (1924) stated that natives grow castor oil plants in their gardens to protect their plantings from ants. The fumes from burning seeds placed on glowing coals in the combustion chamber of an ant fumigation apparatus kill the ants, he stated, and prevent others from reinfesting the nest. Grinberg (1932) stated that *Bothynoderes punctiventris* (Germ.), a beet pest, was killed by feeding on castor bean plants, 10 to 15 being found daily around each plant. He stated that the sap was toxic to the beetle. Jepson (1920) stated that plantings of castor beans as a trap crop for the tea shot-hole borer, *Xyleborus fornicatus* Eich., were effective if the infested bean branches were systematically removed and destroyed. Speyer (1918) said that castor beans were the true host of this insect. Olchovsky (1917) stated that wherever the castor oil plants were grown in the vicinity of cotton plantations the latter were practically free of *Heliothis obsoleta* and *H. peltigera* (Schiff.). Castor beans served as a trap crop. Navas (1923), enumerating the means by which locusts are destroyed, included the growing of plants unsuitable as food for them, such as *Ricinus communis* in Australia. Wolcott (1922) stated that castor oil plants grown near cane will attract many weevils. Newstead (1917) reported *Aspidiotus destructor* Sign. on a castor oil plant. Trochain (1931) pointed out that a grasshopper, *Schistocerca gregaria* Forsk., injured a number of plants, but castor oil plants among others were not attacked; Urich (1915) reported that these plants were attacked by the South American migratory grasshopper, *Schistocerca paranensis* Burm.

Only mention can be made here of the excellent summary of the insects of the castor bean by Myers (1939) which appeared after this manuscript was presented for publication.

The poisonous or insecticidal property of ricin (ricinin), the alkaloid constituent of the plant, has been the subject of some investigation. The question has been summarized by McIndoo & Sievers (1924). In general, they found that the juice from the leaves and green pods of a castor bean plant had only a slight effect on bees. The powdered beans and husks, free of oil, killed all the bees tested; but some of this powder, after having been extracted with a 10 per cent solution of sodium chloride, apparently did not kill any of the bees tested. Several attempts to feed to roaches a dough mixed with the powdered beans failed. The powder had no effect on webworms, but had a slight effect on silkworms, flies and grasshoppers.

An alcoholic extract of castor beans, when reasonably strong and used with soap, was ineffective against three species of aphids, *Aphis* spp. and *Macrosiphum* sp., but the control mixture seemed to have killed half the original number.

Several workers have shown that castor beans contained a specific agglutinin associated with the albumin. It is markedly toxic to the higher animals, and Osborne, Mendel & Harris (1905) report 0.001 milligram per kilogram of animal weight as a fatal dose in rabbits. Wood & La Wall (1926) stated that "the effects of ricin in many directions bear a striking resemblance to the effects of bacterial toxins. Thus, for example, it produces a leucocytosis and an agglutination of red corpuscles. The most interesting, however, of these resemblances is the production of immunity and the formation of antitoxic substances." The various parts of the plant, but particularly the seed, are poisonous to all classes of livestock, especially to horses and sheep. As few as six seeds have killed horses, and two have caused the death of children (Gates 1930).

While ricin may have insecticidal value, experimental results so far have indicated nothing of practical value from it in insect control. The oil has been used in fly and mosquito sprays, in mosquito larvicides, as a regular ingredient with resin in the manufacture of "sticky foot" fly papers and as a repellent for wool maggots.

TESTS WITH GRASSHOPPERS CAGED OVER CASTOR BEAN PLANTS.—Laboratory tests were conducted with cylindrical screen cages 6 by 12 inches over young castor bean plants with 15 individuals of various common economic species of grasshoppers in each cage checked against the same number in a cage on bare soil, and therefore starved, and in a cage over

a clump of alfalfa. Three consecutive series of tests were conducted during July and August. Since it was observed that grasshoppers ate into the juicy stems of castor beans, it was thought the sap was the material sought and was prolonging the lives of the hoppers. A cage in which a vial of tap water with a cotton wick was placed to supply water to the hoppers was added to the above series in two tests. These cages were all kept in a screened, well ventilated insectary in as near optimum conditions as possible for a fair test. The graph in fig. 1 indicates the daily rate at which the hoppers died and were removed from the castor bean and check cages.

The field tests were conducted in cages 4 by 4 by 4 feet over young castor bean plants and over bare soil in the shade of tall castor bean plants (see figs. 4–10). They were checked by a cage of grasshoppers over growing alfalfa containing also pots of corn and brome grass. These tests were run three times; the graph in fig. 2 gives the results of this series of tests. The three castor bean varieties used in the experiments were *Ricinus communis*, *R. zanzibariensis* and *R. variegatus;* at the agronomy farm, plantings were made from seed supplied by Dr. Harry Miller of *R. zanzibariensis*, *R. cambodgensis*, a common variety and a community selection called "Wagner" variety known to have been an imported strain grown on one farm for several family generations.

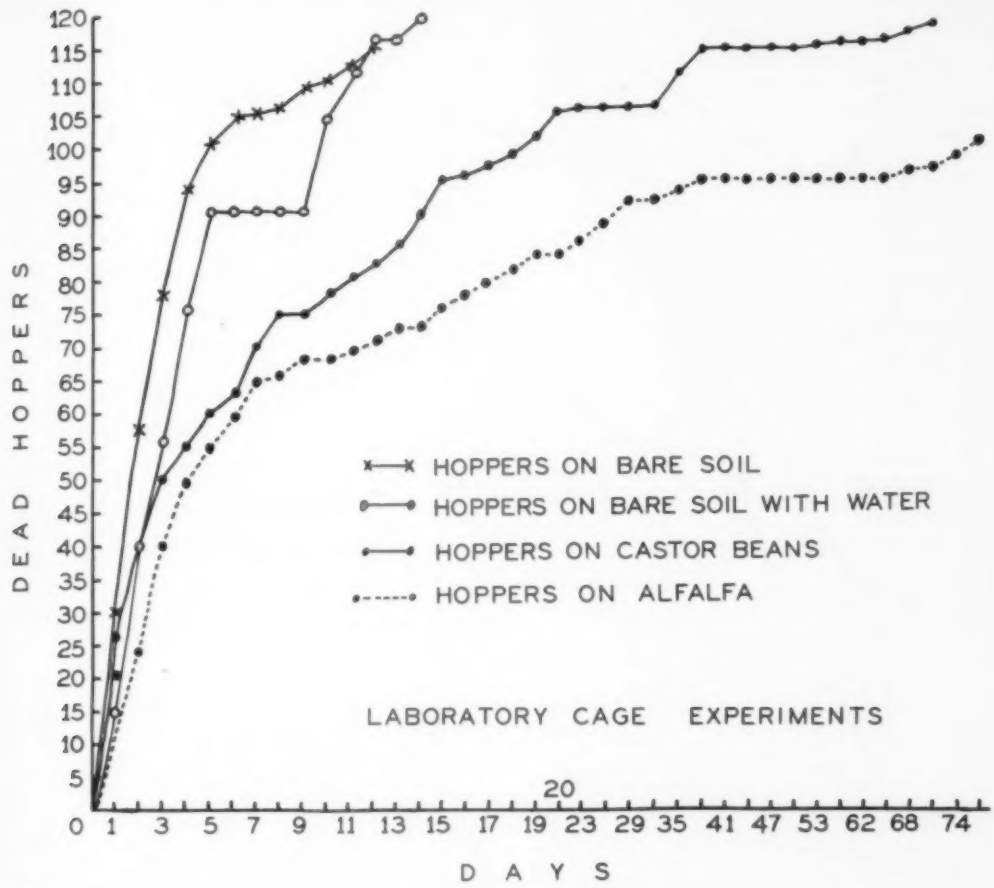

FIG. 1.—A graph indicating the total number of dead grasshoppers of common economic species removed from the three series of insectary laboratory cages in the castor bean food tests during July and August, 1938, at Manhattan, Kan. Note that the interval is daily up to the twentieth day, after which the interval is 3 days.

While the tests were not calculated to bring out small differences between these and common store varieties of castor bean, no significant differences in insect susceptibility or repellence were observed in the field. Difference in plant stem color and other growth features were, however, apparent. In the cage tests, grasshoppers died at practically the same rate when caged on the three common varieties, than under starvation conditions. If the castor bean foliage were toxic to the hoppers action of the poison would have caused them to die rapidly and sooner than through starvation alone. Some grasshoppers adapted themselves to castor beans fairly well and lived as long as 66 days on this plant exclusively. Moisture alone prolonged life over starvation conditions, but the castor beans contrib-

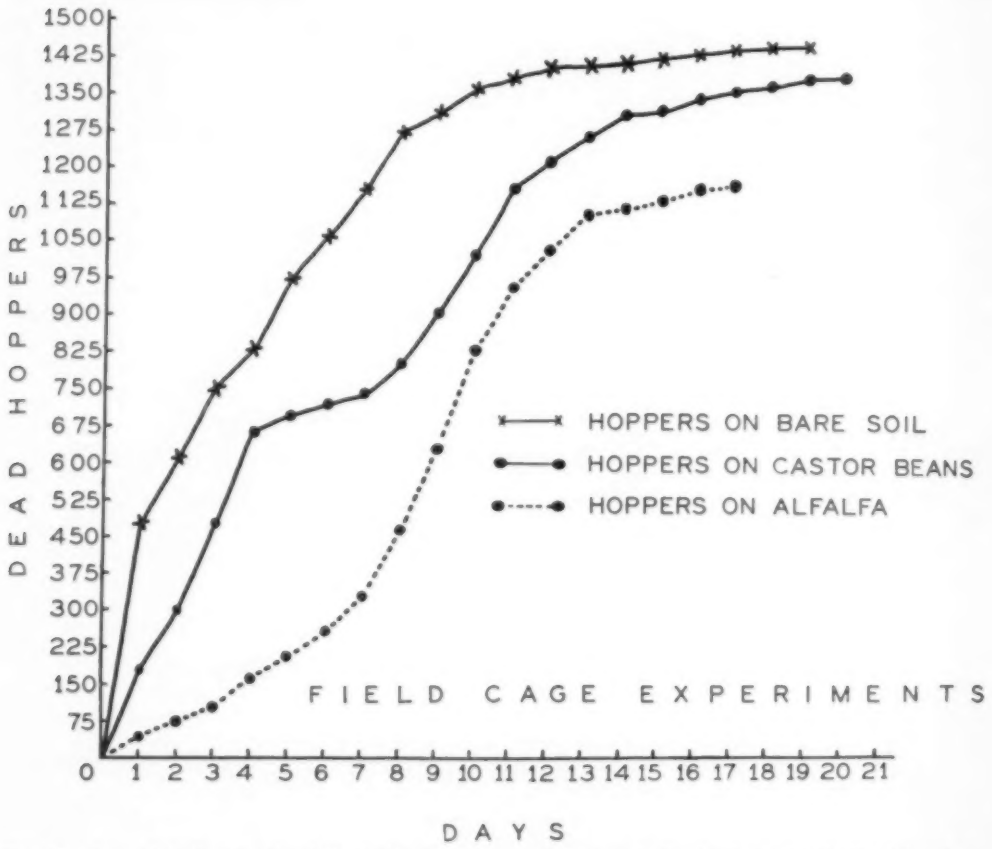

FIG. 2.—A graph indicating the daily death rate in large field cages similar to those used in the laboratory, but outdoors in a patch of castor beans (see figs. 5, 9 and 10).

fig. 3, these plants showing no marked differences in toxicity nor palatibility.

RESULTS OF THE CAGE TESTS.—Graphs in figs. 1 and 2 indicate that grasshoppers live fairly well on an exclusive diet of castor bean foliage and petioles. Alfalfa is a better food, for they died at a slower rate on it and there were many more alive in the alfalfa cages at the close of the tests than on castor beans. However, they were not poisoned by castor bean plants, for they survived better on them uted more of food value than merely the water in the stem or leaves. Twelve egg pods were found in the soil in the castor bean cages.

GRASSHOPPER FEEDING OBSERVATIONS.—It was clear that grasshoppers did not relish any part of the castor bean plants for food. Some individuals refused to eat the foliage and grew weaker from lack of food. Others either from weakness or mild poisoning appeared to be partly paralyzed, in which condition they often

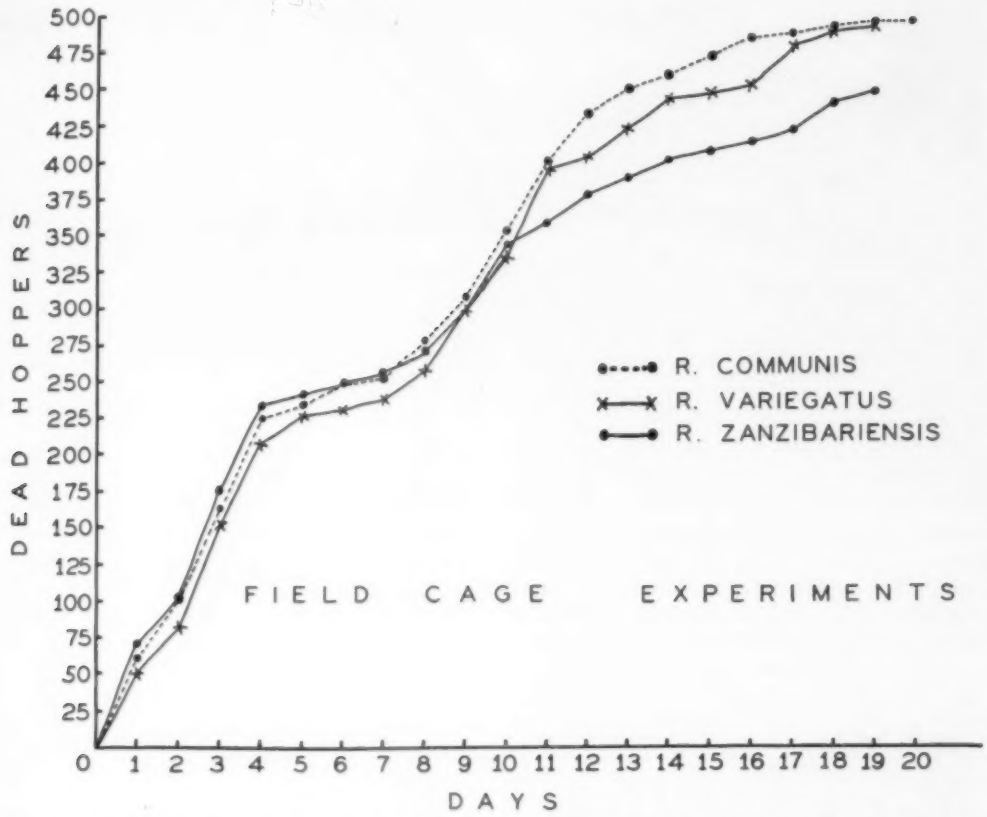

FIG. 3.—Graph showing the daily rates at which dead grasshoppers were removed from three large field cages over three varieties of living castor bean plants. In all three graphs, the heaviest death occurs in the first 3 or 4 days. Part of this loss is due to injury incident to the collection and caging of the hoppers.

FIG. 4.—General view of the experimental plot of three varieties of castor bean plantings upon which insect collections were made, and which were used in the grasshopper feeding experiments.

FIG. 5.—Large cage over variegated variety of castor beans used in the grasshopper feeding experiments described in this paper. Partial results of this experiment are indicated in fig. 3.

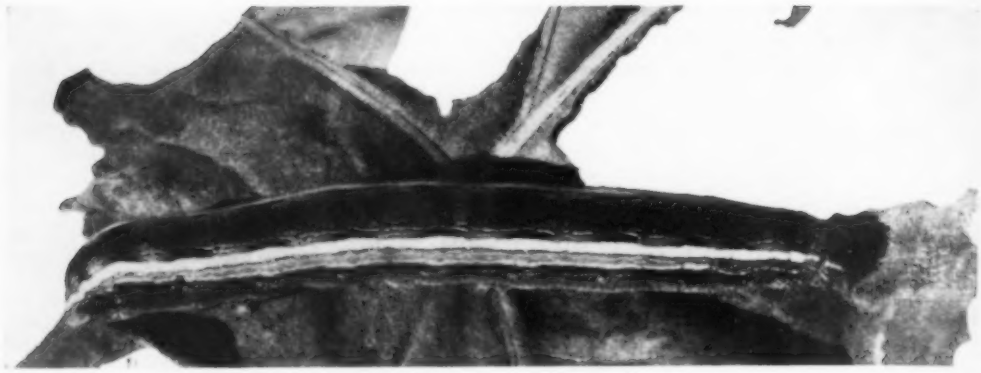

FIG. 6.—Cotton cutworm or yellow-striped armyworm. This caterpillar matured on castor beans.

survived for as long as 3 days. They would lie on their sides or backs, but when disturbed would be able to walk or jump a short distance. Grasshoppers fed upon both the foliage and leaf petioles of the castor bean, fig. 7. Leaves often became ragged in the cages and some petioles were nearly severed.

In one cage, pots of a variety of plants commonly fed upon by grasshoppers were placed beside young, potted castor bean plants. It was clear from the differential feeding that grasshoppers preferred wheat, corn and alfalfa to castor bean plants, for these plants were more or less severely eaten, while the castor bean

FIG. 7.—Young potted castor bean plant in a cage with grasshoppers; typical grasshopper injury to foliage is shown. This plant was kept in the cage until all the hoppers had died.

plants were untouched until other food was gone. It has been variously stated that during the grasshopper flights in the great plains, 1870–75, not infrequently the grasshoppers ate "every living plant except castor beans."

In field plantings of castor beans, the foliage of the castor bean was in some cases untouched; in others it was evidently fed upon. A few instances were seen where the foliage was somewhat ragged, but no instances were seen where grasshoppers were killed or poisoned by castor bean foliage. Dead grasshoppers killed by bran mash sowed in adjoining plots were found under the castor bean plants at the agronomy farm. The cause of death was determined by breaking the dead grasshoppers open and finding the plug of bran mash in the crop. Other grasshoppers were killed by mermid and sarcophagid parasites. In most of the tests, the dead grasshoppers were either dissected to learn the cause of death or they were kept to await emergence of the parasites. No parasites were found in the dead hoppers from the laboratory cages, but both mermids and sarcophagids were obtained from those in the field cages. It is believed that the great majority of hoppers in all cages died from starvation, disease and parasites rather than from being poisoned.

FIG. 8.—Young castor bean plants cut off by the dark-sided cutworm. This injury occurred in the observation plot (see fig. 4).

FIG. 9.—Field cage over *Ricinus zanzibariensis.*

The supposed attractive value of castor beans may have arisen from seeing grasshoppers and other insects alight on castor bean plants. Castor beans grow tall, almost treelike, and offer perches, shade

FIG. 10.—Cage over *Ricinus communis,* the common variety of castor beans.

and a certain amount of protection from enemies. Food attractiveness is not necessarily involved when insects perch on stems or leaves.

Three tests of confined, young, newly hatched grasshoppers in screened cages over young, succulent castor bean plants showed that in general half of the young hoppers were dead at the end of 48 hours, one-fourth more in 72 hours and the remainder in 96 hours. Only slight feeding was done on the plants, judged by their appearance.

It was necessary to remove daily the dead grasshoppers from all cages, but especially those from the castor bean cages, because the hungry grasshoppers devoured them instead of feeding on the bean foliage. Feeding on dead hoppers would enable those still alive to live longer and give a false value for length of life.

ANNOTATED LIST OF INSECTS FOUND ON CASTOR BEAN PLANTS IN KANSAS, 1938

ORTHOPTERA

Melanoplus bivittatus (Say). The two-striped grasshopper. In outbreak, 1938. Foliage and petiole feeding.
Melanoplus differentialis (Thos.). The differential grasshopper. Same as above.
Melanoplus femur-rubrum (De G.). The red-legged grasshopper. Common in 1938.
Melanoplus mexicanus (Sauss). Migratory grasshopper. In outbreak, 1938.
Dissosteira carolina (L.). Carolina grasshopper; normal population, 1938. Foliage feeder.
Dichromorpha viridis (Scudd.). The common green grasshopper; a grass feeder.
Hippiscus rugosus (Scudd.).
Phoetaliotes nebrascensis (Thos.).
Aulocara elliotí (Thos.).
Schistocerca obscura (F.).
Orchelimum vulgare Harr. A green grasshopper. Scarce, incidental.
Oecanthus angustipennis Fitch. A tree cricket, as above.
Oecanthus nigricornis argentinus Sauss. As above.

NEUROPTERA

Chrysopa plorabunda Fitch. The common lace wing Abundant, 1938. Incidental.

COLEOPTERA

Hippodamia convergens Guér. Convergent ladybeetle. Incidental.
Mordella oculata Say.
Haltica lazulina Lec. A green flea beetle.
Chaetocnema protensa Lec. Small black flea beetle.
Epitrix lobata Cr. Same. Smaller.
Epicaerus imbricatus Say. Imbricated snout beetle.

HEMIPTERA

Brochymena arborea Say. A broad, flat pentatomid, abundant during 1938.
Blissus leucopterus (Say). The chinch bug. Incidental.
Adelphocoris rapidus (Say). The rapid plant bug. Numerous during 1938, but incidental on this plant.
Empoasca fabae (Harr.). Potato leafhopper. Abundant, 1938; on potatoes nearby.
Aphis spp. Winged aphids. Incidental.

LEPIDOPTERA

Papaipema nebris nitela (Guen.). Common stalk borer present in the stalks.
Lycophotia margaritosa saucia Hbn. The variegated cutworm. Larvae cut off some young plants.
Euxoa messoria (Harr.). The dark-sided cutworm. Larva around the roots injuring some plants.
Feltia venerabilis Walk.
Laphygma frugiperda (S. & A.). Fall armyworm.
Prodenia ornithogalli Guen. Yellow-striped armyworm. Larvae fed on foliage.
Loxostege similalis (Guen.). The garden webworm.
Haematopis grataria (F.). The chickweed moth.
Plathypena scabra (F.). Green clover worm.
Atalopedes campestris Bdv. A skipper.
Pyrgus tessellata Scudd. Black and white skipper.
Pieris rapae (L.). The imported cabbage worm. Incidental.
Eurymus eurytheme (Bdv.). Alfalfa caterpillar. Abundant during 1938. Incidental.
Anaea andria Scudd. Goat weed butterfly. Incidental.

HYMENOPTERA

Bruchophagus funebris (How.). The clover and alfalfa seed chalcid. Abundant in alfalfa plots nearby.
Harmolita sp.
Spilochalcis spp.
Callimome brodiei (Ashm.)
Callimome sp.
Eurytoma sp.
Metapon sp.
Pteromalus sp.
Macroteleia sp.
Perilampus chrysopae Cwfd.
Perilampus similis Cwfd.
Ceratosmicra sp.
Chalcis spp.
Ophion bilineatum (Say). An ichneumonid parasite of lepidopterous larvae.
Tiphia sp. Medium sized vespoid at the blossoms.
Stizus unicinctus Say.
Dasymutilla quadriguttata (Say). A velvet ant; females on the ground.
Chlorion atratum (Lep.). A sphecid wasp.
Polistes variatus Cress. A common polistes wasp; abundant at the nectaries.
Polistes minor Beau. Similar in habits to above; smaller in size.
Sphex arvensis vulgaris Dahlb. A sphecid wasp. Common at nectaries.
Sceliphron coementarium (Dru.). A sphecid wasp. Common at nectaries.
Notogonia argentata Beau. A common, small, nearly black sphecid wasp.
Camponotus herculeanus subsp. *pennsylvanicus* (DeG.). One of the larger, wingless ants on castor bean plants. (Ants determined by M. R. Smith.)
Monomorium minimum (Buckl.). The smallest black ants on the plants; common at the nectaries.
Crematogaster opaca depilis var. *punctulata* Em. A medium sized species; as above.
Crematogaster lineolata (Say)

Crematogaster sp.
Pheidole pilifera (Roger)
Pheidole imparis (Say)
Apis mellifera L. Common honeybee, at the flowers.
Halictus sp. Common solitary bee; abundant on blossoms.
Hedychrum sp.
Chelonus sericeus Say.

DIPTERA

Deromyia ternata Loew. A predator seen to destroy a specimen of *Sceliphron coementarium*.
Syrphus weidemanni John. A common flower fly.
Sciapus sipho Say. A common dolichopodid fly. Predacious.
Psilopus caudatus Wied. As above.
Tetanops luridipennis Loew. A scavenger fly.
Eugnoriste occidentalis Coq. A small fungous gnat.
Chloropisca glabra (Meig.). The most common chloropid.
Crassiseta costata Loew.
Hippelates pallipes (Loew.).
Sarcophaga kellyi Ald. Grasshopper maggot, the common sarcophagid parasite of grasshoppers.
Sarcophaga assidua Walk. A common sarcophagid.

UNIDENTIFIED SPECIES.—In addition to the species listed, the names of which were obtained largely by comparison with determined specimens in the departmental collection, there remains a considerable number of unidentified small Diptera and Hymenoptera. It is believed that all of these undetermined specimens and the great majority of the forms listed herewith are parasites or incidental visitors feeding on nectar and do no injury to the plant.

Only a few of the insects listed ever fed on any part of the castor bean plant. Many were attracted by the nectar in the blossoms and the products of the accessory nectaries on the stems. Many stopped to rest on the plants, or in the shade afforded by their luxuriant growth and were merely incidental visitors. Others were predators and came to feed on the insects gathered there. Almost all of them are common insects which were present on nearby crops, which were alfalfa, sweet clover, wheat, corn, grasses and various garden plants. Not one of the insects listed feeds by preference on castor beans. All castor bean plantings seen were remarkably free from insect damage; so, if the plant is grown commercially in this region, insect damage is unlikely to be a factor of importance.

SUMMARY AND CONCLUSIONS.—This paper records a list of approximately 75 insects collected on field plantings of castor beans in Kansas, and summarizes the results of two series of cage rearings, laboratory and field, of grasshoppers on castor beans, on alfalfa and on bare soil or under starvation condition. It was apparent that grasshoppers did not relish castor bean foliage, and, when given an opportunity, fed upon various common plants in preference to it. It is concluded, therefore, that castor beans cannot be used as a trap crop because they are not more attractive to grasshoppers and other common pests than the usual crop food plant.

Since grasshoppers died in the castor bean test cages at a rate intermediate between the rate on alfalfa and that under starvation conditions, no evidence of poisoning could be observed; otherwise grasshoppers would have died faster in the castor bean cages than on bare soil. While castor beans are apparently objectionable to grasshoppers, crops cannot be adequately protected by border or strip plantings because of the easy mobility of the hoppers. It is concluded, therefore, that no evidence of any value of castor beans for poisoning, repelling or trapping grasshoppers or any other crop insect pest was observed during the season of 1938. No real protection was observed in farm plantings and none was reported by farmers.

This does not affect the chemurgic and agricultural values of the plant. The plant and the beans are not seriously attacked by insect pests. An important addition to farm crops may be near, but the value of present-day varieties of castor beans in farm insect control is nil.—1-16-39

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Protein Lures for Fruitflies

M. McPHAIL, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine*

The observations herein recorded on protein lures represent a division of a larger series of experiments on fruitfly lures in general. Publication of these observations appears advisable because it is believed that they will find practical application in combating a number of species of destructive fruitflies.

The experiments were performed at Cuernavaca, Morelos, Mexico, 1933–34. Two species of fruitflies occur in the area in large and destructive numbers, the Mexican fruitfly, *Anastrepha ludens* Loew, and the Central American fruitfly, *A. striata* Schiner. The former attacks a number of cultivated fruits, whereas the latter is essentially a pest of guavas. Both species were taken to the present experiments; therefore, in the data to follow the response of the two species is recorded. However, only one species, *A. striata*, the guava fly, responded favorably.

EXPERIMENTAL PROCEDURE.—The experimental procedure consisted in comparing the performance of protein preparations with that of fermenting brown sugar, the control lure. Glass traps were employed. Test traps and control traps, not less than 8 feet apart, were set at random in the trees. There were 12 to 24 traps in each test. Half of these were baited with a protein preparation and the other half with the control lure. The exposure periods ranged from 5 to 8 days.

PRELIMINARY TESTS WITH PROTEIN IMPURITIES.—Interest in proteins as lures for fruitifles had its inception in experiments designed to determine whether impure sugars undergoing hydrolyzation would lure flies. In the first test piloncillo (Mexican brown sugar), which contains considerable invert sugar, was used. Piloncillo is a very crude product, much below ordinary brown sugar in purity. The catch of *Anastrapha striata* was good, showing that the preparation was definitely attractive. As a check on the results, two commercial sirups were substituted for the piloncillo. The first sirup was not attractive, and the second only

Table 1.—Preliminary field tests with protein impurities.

Test No.	Lure	Number of Fruitflies Taken			
		Anastrepha striata		*Anastrepha ludens*	
		Control	Test	Control	Test
1	50 grams piloncillo, 1 liter water, 4 grams sodium hydroxide, held at 50 degrees C. for 2 days prior to exposure in the field	44	47	78	10
2	Same as no. 1 except that 40 grams sodium hydroxide were used	44	60	78	10
3	100 grams of a commercial sirup, 1 liter water, 40 grams sodium hydroxide, held for 20 hours at 50 degrees C. prior to exposure in the field	50	0	85	2
4	Same as no. 3 except that a different sirup was used	50	9	85	5
5	Concentrated alcoholic precipitate of piloncillo solution in sodium hydroxide solution (80 grams NaOH, 1 liter water); no heat applied	89	202	171	46
6	Same as no. 5 minus the sodium hydroxide	89	42	171	30

mildly so. Meanwhile a study of the impurities in the piloncillo was undertaken in the laboratory. The presence of protein was demonstrated in three ways: (1) When the sugar was dissolved in sodium hydroxide solution and then heated, a noticeable odor of ammonia developed. (2) When the sugar was cooked in limewater, a proteinlike foam rose to the top. (3) When alcohol was added to a solution of water and sugar, a precipitate was thrown out which was apparently protein. This protein, when concentrated and exposed in the traps in sodium hydroxide solution, proved to be very attractive to *striata*. The data for these preliminary field tests are given in table 1.

TESTS WITH VARIOUS PROTEINS.—After these preliminary experiments, the study was concentrated on proteins. The object was to find a combination which would attract *Anastrepha ludens* well also. Casein and gelatin were the only pure proteins available. Other substances tested were fresh baker's yeast, filter-press mud (a by-product in the manufacture of sugar), cow hide with hair attached, cow blood, white of egg and wheat shorts. The data for these tests are given in table 2. Good attraction of *A. striata* was obtained with each of these materials, but none proved very attractive to *A. ludens*.

The proportions of ingredients as given in table 2 were arbitrarily adopted. That they may be far from the most economical and effective combinations may be

Table 2.—Attractiveness of different protein lures to fruitflies.

Test No.	Lure*	Number of Fruitflies Taken			
		Anastrepha striata		*Anastrepha ludens*	
		Control	Test	Control	Test
1	50 grams casein, 80 grams sodium hydroxide	42	236	19	1
2	50 grams gelatin, 40 grams sodium hydroxide	130	210	53	8
3	Whites of three eggs, 80 grams sodium hydroxide	7	54	14	2
4	112 grams fresh cow hide (hair attached), 80 grams sodium hydroxide	77	289	229	99
5	150 grams fresh cow hide (hair attached), 80 grams sodium hydroxide, held for 5½ hours at 50 degrees C.	156	318	118	14
6	80 grams filter-press mud, 80 grams sodium hydroxide	34	123	84	16
7	Same as no. 6 without the sodium hydroxide	34	4	84	0
8	120 grams fresh baker's yeast, 80 grams sodium hydroxide	42	37	19	7
9	Fresh cow blood, 30 grams borax	—	1	—	0
10	Fresh cow blood, 40 grams sodium hydroxide	—	191	—	7
11	Borax-water extract of wheat shorts (80 grams shorts, 15 grams borax, 1 liter water), 28 grams sodium hydroxide	53	136	64	12

* Materials added to 1 liter of water.

Table 3.—Effect of protein content on attractiveness of the lures to *Anastrepha striata* (lure constant = 1 liter water, 80 grams sodium hydroxide).

INGREDIENT	GRAMS	RATING
Casein	25	1.00
	50	1.10
	100	1.51
Gelatin	12	1.00
	25	1.35
	50	1.21

assumed from tables 3 and 4, which give the results of experiments with different proportions of casein or gelatin, or of sodium hydroxide.

Although very preliminary, these data indicate what might be expected from lures containing different proportions of ingredients. Casein proved rather difficult to handle in these tests. It formed into lumps in the sodium hydroxide solution, making it hard to obtain an even distribution of protein in the traps. This difficulty, it was found, could be overcome by mixing the casein with water before adding the sodium hydroxide.

OTHER HYDROLYTIC AGENTS.—Sodium hydroxide was used as the hydrolytic agent in the present experiments because a quantity of the commercial product was on hand. Potassium hydroxide should be equally effective. Lime might be used, although its poor solubility and whitewashing effect would constitute problems in connection with trap operation and limit its use for scouting purposes. Enzymes were considered. Dilute egg white treated with pepsin was attractive to *Anastrepha striata*, and the attractiveness of fermenting brown sugar solution was increased by adding casein, indicating that organisms might be used.

WHY DECOMPOSING PROTEINS ATTRACT.—The reason proteins, altered by treatment with strong alkali, were attractive to *Anastrepha striata* was considered. Materials possibly formed during the treatment, namely, tyrosine, cystine, d-glutamic acid (practical), l-aspartic acid, dl-alanine and glycine (practical), dissolved in water, were tested separately. A dilute solution (3 grams in 2 liters) of glycine appeared to be attractive (control 26; glycine 137). The same concentration of dl-alanine caught some flies (control 91; dl-alanine 44), as did also l-cystine (control 57; l-cystine 13). It is not possible to say, however, that the attractiveness of these solutions was due partly or solely to these amino acids. An exposure period of 7 days was used. During that time bacterial action may have set in and the amino acids may have decomposed. When the traps were examined, it was observed that a considerable proportion of the flies captured in the glycine traps were still alive, which suggests that the material was most effective during the latter part of the exposure period, owing, perhaps, to decomposition.

The odor of ammonia was evident in a number of the preparations. As a matter of fact, gelatin was the only substance tested which the writer can say did not liberate ammonia. With some of the materials an attempt was made to correlate

Table 4.—Effect of sodium content on attractiveness of the lures to *Anastrepha striata* (lure content = 50 grams gelatin, 1 liter water).

SODIUM HYDROXIDE ADDED, GRAMS	RATING
20	1.00
40	1.03
80	0.92
160	0.95

the rate of ammonia production with attractiveness. The Folin aeration method was used to measure the amount of ammonia produced. With casein, although the period of maximum ammonia production appeared to parallel the period of greatest attractiveness (first 3 days), dilute ammonia water caught comparatively few flies. The fact that lures made with gelatin were attractive indicates that ammonia alone is not responsible for attractiveness.

REACTIONS OF OTHER FRUITFLIES.—It appears that *Anastrepha striata* is typical of a number of fruitflies in its reaction to ammonia and ammonia compounds, including decomposing proteins. *Anastrephe ludens*, on the other hand, appears distinct. Starr & Lau*† have found that the

* Starr, Donald, and Kam Hu Lau. Casein and yeast lures for the Mediterranean fruitfly (*Ceratitis capitata* Wied.). Report No. 50-R, Honolulu Laboratory, Division of Fruitfly Investigations, Bureau of Entomology and Plant Quarantine. (Unpublished.)

† Starr, Donald, Attractants for the melonfly (*Dacus cucurbitae* Coq.). Report No. 52-R, Honolulu Laboratory, Division of Fruitfly Investigations, Bureau of Entomology and Plant Quarantine. (Unpublished.)

Mediterranean fruitfly, *Ceratitis capitata* Wied., and the melon fly, *Dacus cucurbitae* Coq., are of the *striata* type, and McAlister‡ has observed the same to be true of *Anastrepha suspensa* Loew and *A. mombinpraeoptans* Sein.

SUMMARY.—It is shown that proteins in the presence of sodium hydroxide solution made very satisfactory field lures for the Central American fruitfly (*Anastrepha striata* Schiner). The following proteins or substances containing protein were tested individually: Casein, gelatin, filter-press mud, baker's yeast, cow hide with hair attached, cow blood, white of egg and wheat shorts. Each produced an attractive lure, indicating that the phenomenon was true of proteins in general.

Preliminary studies on concentration of lure with respect to protein content and sodium hydroxide content suggested fruitful fields of study, as did also a consideration of hydrolytic agents other than sodium hydroxide.

Products of protein hydrolysis were considered. Some of the amino acids appeared promising.—2-13-39.

‡ McAlister, L. C., Jr. Annual progress report on the West Indian fruitfly in Puerto Rico during 1937. Division of Fruitfly Investigations, Bureau of Entomology and Plant Quarantine. (Unpublished.)

Planting Dates as Affecting Wireworm Injury to Potato Tubers

W. A. RAWLINS, *Cornell University, Ithaca, N.Y.*

The production of high quality potatoes is of increasing concern to potato growers in upstate New York. It is a complex problem due to the diversity of injuries that are caused by insects, diseases, physiological factors and the mechanical handling during harvest and marketing. The injuries caused by insects, particularly wireworms, are widespread throughout most potato growing areas, and in many instances wireworm injury is the most important of the tuber defects.

A number of species of wireworms have been collected from potato fields, but only three species are common and numerous. The wheat wireworm, *Agriotes mancus* (Say), and the eastern field wireworm, *Limonius ectypus* (Say), are most abundant and consequently most injurious, although in a few cases corn wireworms, *Melanotus* sp., have caused considerable damage. For a number of years investigations were chiefly concerned with the control of the wheat wireworm, but it was soon evident that measures recommended for the wheat wireworm were not effective against the eastern field wireworm. The results reported in this paper are from studies conducted on the eastern field wireworm during the last 2 years.

WIREWORM INJURY AND INFESTATION.—Wireworm injury is confined to the underground parts of potato plants such as tubers, stems, stolons and seed pieces. Injuries to the growing tubers vary from surface scars to tunnels which extend deep into the flesh of the tubers. In many instances a number of wireworms have entered the same tuber and have completely honeycombed the interior. Tunneling of the seed pieces enables rot organisms to cause an early breakdown or decay of the food material essential for the early growth of the potato plant. Extensive wireworm injury to growing stems has been noted in a number of heavily infested fields from the time of sprout emergence until the stems became hard and woody. Girdled plants are sometimes killed, but usually the damaged plants are stunted and produce many small worthless tubers immediately below the soil surface. This injury is similar to that caused by the *Rhizoctonia* fungus and may be confused with that injury. Damage to seed pieces and underground portions of the stems, although considerable in many instances of heavy wireworm infestations, is of little consequence. Injury to tubers produced during the growing season is of primary importance to potato growers due to reduction in the market quality of the crop.

For a number of years field observations have repeatedly shown that infestations of eastern field wireworms were found almost exclusively in sandy types of soil. In the potato producing areas these soils are highly productive and are cropped continuously with potatoes and

other cultivated plants. In spite of extensive use on these soils of the short rotation of row crops, eastern field wireworm infestations have persisted and in many cases have markedly increased.

Previous investigations (Rawlins 1934, 1936) in western New York on the wheat wireworm, *Agriotes mancus*, showed that infestations of this wireworm started in long standing sod crops such as clover, timothy and alfalfa and to some extent in wheat and spring grain crops. Particularly in the dairy farming regions potatoes are grown in rotation systems after sod or hay crops. Substitution of cultivated or row crops for long standing sod in these potato rotations has eliminated wheat wireworm infestations and reduced wireworm injury to a negligible amount within 2 to 3 years.

As a general rule, larvae of *Agriotes mancus* are most abundant in heavy soils of the silt loam and clay loam types. No instances have been noted where heavy wireworm infestations of both *Limonius ectypus* and *A. mancus* have occurred in the same field. It is true that light infestations of *A. mancus* have been found in wireworm populations which were predominantly *L. ectypus*. It is believed that soil characteristics and different farm practices have resulted in a rather complete segregation of the two species even within the same region.

Obviously the method of control, that is, continued cropping of infested fields with row crops as recommended for the wheat wireworm, could not be effectively applied to the eastern field wireworm since infestations of this species start in cultivated fields. The search for other methods of reducing wireworm population and injury to the potato crop, particularly those methods involving cultural practices, has not proved very successful. However, the date of planting of the seed tubers and the time of tuber set has been found to have a very significant effect on the amount of tuber damage.

Of interest was the frequent observation of growers producing potatoes on fields infested with *Limonius ectypus* larvae that few wireworms were found at harvest time either feeding on the tubers or near them in the hill. In making preliminary studies in 1936 on the life history of *L. ectypus* it was noted that the wireworms migrated downward some distances from the tubers during the first week of September. Furthermore, at digging time in October potatoes that were planted late in the planting season were not so severely injured as potatoes planted early, although wireworm infestations were large in both cases.

The potato planting season varies considerably in different potato growing areas of upstate New York. In Monroe County, where the investigations herein reported were carried out, the planting period extends from the first week in May to the latter part of June. The growing period for potatoes in this region is approximately 90 to 110 days. Killing frosts occur generally during the last 2 weeks of October.

FIELD EXPERIMENTS.—With the above information in mind the author conducted field experiments during the seasons of 1937 and 1938 to determine more fully the relation of time of planting to the amount of wireworm damage. This work has been carried out on two fields heavily infested with eastern field wireworms. The soil in one field is classed as "Genesee fine sandy loam" and in the other field the soil is classed as "Worth fine sandy loam" (Sweet *et al.* 1938). One experiment was conducted in the first mentioned field in 1937 and repeated in two similar plantings, both the fields mentioned being used in 1938.

Plantings were made at approximately 2-week intervals beginning in May and ending during the first part of July. Seed pieces were planted by hand at a depth of 4 inches in a well-prepared seed bed. The plots were 50 feet long in two experiments and 100 in the other experiment and were arranged in a Latin square plot design. Data have been analyzed statistically by the analysis of variance. One row plots were used in the 1937 experiment, but, with the possibility of migration of the insects from plot to plot, three and four row plots were used in the 1938 experiments, thus providing outside buffer rows. However, data obtained from these latter experiments indicated that wireworms do not migrate from plot to plot and that only one row is necessary for accuracy.

During the growing season frequent observations were made to determine the time of tuber set in each series of plots planted at the same time. The dates are

Table 1.—Date of planting and tuber set as affecting wireworm injury to potato tubers, 1937.

Date of Planting	Approximate Date of Tuber Set	Per Cent of Wireworm Injury	Percentage of Tubers With 1 Puncture	2 to 5 Punctures	6 or More Punctures
May 19	July 15	88.8	29.3	29.5	30.0
June 3	August 3	65.3	29.8	17.0	18.5
June 23	August 23	35.0	21.2	9.8	4.0
July 7	September 1	14.5	11.0	3.0	0.5
Least significant differences for odds 19:1		11.2	7.9	7.8	9.9

approximate, due to the variation in growth and tuberization of plants in the same series. When, however, the largest tubers reached a diameter of one-half inch the tubers were considered set. Frequently wireworms were noted feeding on tubers of this size.

Counts of injured tubers were made from representative samples taken from each plot at digging time in late October. The numbers of injured tubers were recorded, together with the severity of injury which was classified roughly as slight, moderate and severe. These classifications were based upon the numbers of punctures in each one of the tubers counted and separated as tubers with one puncture, tubers with two to five punctures and tubers with six or more punctures.

In the 1937 experiment four plantings were made at approximately 2-week intervals starting on May 19, the last planting being made July 7. Tuberization began 56 to 61 days later and was recorded from the respective plantings on July 15, August 3, August 23 and September 1. All plots were harvested and counts of wireworm injury were made on October 14. The results are summarized in table 1 and show a very definite relation to the date of planting and date of tuber set. Injury was severe on tubers from the plots planted May 19 and decreased progressively with each successive planting. Severity of injury as classified according to the number of punctures in each tuber also showed a similar relationship. Within each classification, with one exception, percentages of injured tubers were consistently less for consecutive plantings. Furthermore, the proportion of tubers with two to five punctures and six or more punctures, that is, those moderately and severely injured, decreased with each later planting.

Findings from both of the 1938 experiments, table 2, substantiated results of the previous year's work. Five plantings were made at intervals of 12 to 20 days from May 5 through July 6 in one field and from May 20 through July 15 in the other. Tuber setting in the former occurred in 61 to 64 days after planting for the first four planting dates and in 54 days for the last planting. In the second

Table 2.—Date of planting and tuber set as affecting wireworm injury to potato tubers, 1938

Date of Planting	Approximate Date of Tuber Set	Per Cent of Wireworm Injury	Percentage of Tubers With 1 Puncture	2 to 5 Punctures	6 or More Punctures
		Field I			
May 5	July 7	64.0	30.2	18.8	13.0
May 19	July 21	42.6	24.0	11.0	7.6
May 31	July 30	33.6	20.0	10.4	3.4
June 16	August 19	17.4	11.6	4.8	1.0
July 6	August 29	8.8	6.0	2.8	0.0
Least significant differences for odds 19:1		14.3	3.5	4.4	5.5
		Field II			
May 20	July 15	38.8	22.4	10.6	5.8
June 3	July 29	43.6	22.6	15.6	5.4
June 17	August 18	27.4	19.0	8.2	1.4
July 1	August 26	12.0	9.6	2.2	0.2
July 15	September 3	5.2	4.4	0.8	0.0
Least significant differences for odds 19:1		9.5	5.4	5.3	4.5

field for the first four dates tuber setting was recorded 56 to 62 days after planting and after 50 days for the last planting. Although the infestations of wireworms were approximately the same in all experiments, the amount of injury to the tubers was less in 1938 than in 1937. The trend in the amount and severity of tuber injury, however, was much the same as that in the previous year's experiment. For each successive planting date decreases were consistent with one exception. In field 2 the first two plantings were injured about equally.

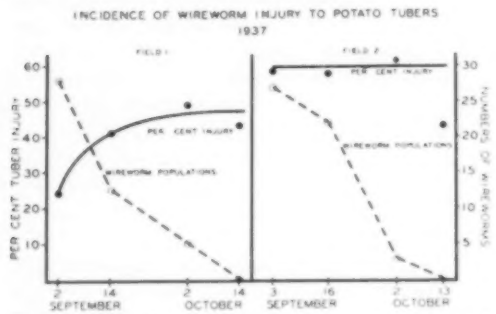

FIG. 1.—Trends in wireworm populations and amounts of injury to potato tubers from 25 hills harvested on each of four dates during September and October, 1937.

An explanation for the decreases in tuber injury on late planted potatoes was evident from certain field data obtained for the purpose of determining the advisability of early harvest to escape late season wireworm feeding. A number of observations were made at intervals during the growing season to determine incidence of injury, the rate of increase of injury and the period of wireworm feeding. The data were obtained from two heavily infested fields in 1937, fig. 1, and from the first planting of the 1938 planting date experiment located in field 2, fig. 2. Sampling was started in 1937 on September 2 and 3 when the potato plants were showing signs of maturity. On these dates the yield of tubers was slightly more than one-half the final yield. The following year the first harvest was made shortly after tuber set on July 20.

For each harvest 25 plants were selected at random and the number of tubers, number of injured tubers and wireworm populations were noted from individual hills. All of the soil immediately surrounding the tubers was removed and carefully examined for wireworms. Each sample approximated an area 1 foot square and 6 inches in depth. All tubers were found within this area and it is assumed that wireworms found therein were probably feeding at the time the sample was made. However, feeding activities and migrations to and from the hill are incompletely known at the present time. In each of the two fields from which the 1937 data were obtained sampling was done in the same area, which was selected for uniformity of infestation and plant stand. The following year, plot rows in the date of planting experiments were long enough to permit several sample counts, as well as the final harvest for yield and wireworm injury.

RESULTS. Referring to fig. 1, it will be noted that wireworm populations within the potato hills decreased sharply after the first counts on September 2 and 3. At the time of the last count, on October thirteen and fourteen no wireworms were found near the tubers. While the wireworm injury trends are not identical for the two fields, it is evident that the percentage of injured tubers did not increase significantly after the middle of September. In field 2 the amount of injury remained about the same for each sampling date. The decrease that was recorded on October 13 was undoubtedly an aberrant case.

The incidence of injury and wireworm populations in the hills of potatoes is more clearly shown from the 1938 sampling data graphically indicated in fig. 2.

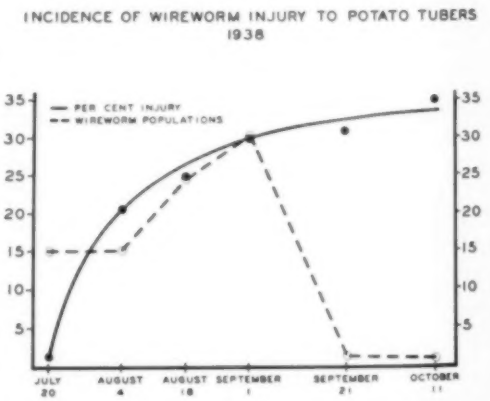

FIG. 2.—Trends in wireworm population and amount of injury to potato tubers from 25 hills examined on each of six dates during the growing period of 1938.

From a period beginning July 20 shortly after tuber set until September 1, wireworm injury increased rapidly. After the latter date, however, only a slight increase was observed. Wireworm populations in the potato hills increased during August but decreased sharply after September 1. These data therefore substantiate those of the previous year.

It is apparent from the evidence submitted that the eastern field wireworms ceased to feed after the first part of September and migrated away from the immediate vicinity of the tubers. Incidental studies have shown that most of the wireworms burrow downward sometimes as far as 2 feet. It was interesting to observe that in this species only a portion of the population was apparently attracted to the potato hill at any one time during the summer. In fact, an average of approximately 50 per cent was near the tubers during August when the largest number of wireworms was recorded in the potato hills. The remaining portion of the population was either between rows or below the 6-inch level.

The results of these studies show that in western New York potatoes should be planted as late in the planting period as is economically feasible. Early planted potatoes were more severely injured by the eastern field wireworms than late planted potatoes. The evidence presented shows that the wireworms ceased feeding in early September and migrated away from the potato hills. Since late planted potatoes set tubers in late August the crop is not subject to wireworm attack for as long a period as early planted potatoes which set tubers in late July and early August.—5-2-39.

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Two Simuliids Found Feeding on Turkeys in Virginia

G. W. UNDERHILL, *Virginia Agricultural Experiment Station, Blacksburg*

It has been established (1938) that *Simulium nigroparvum* Twinn may transmit *Leucocytozoon smithi* a protozoan disease of turkeys; therefore, a study of the species of blackflies that feed on turkeys is being made. Two species have been taken while feeding on turkeys, *S. nigroparvum** and *S. slossonae* (D. & S.). *S. occidentale* Townsend, which was reported by Skidmore (1932) to feed on turkeys in Nebraska, has not been collected by the author of this paper.

METHODS.—Larvae, pupae and cocoons of blackflies were collected in different types of streams in 64 counties of Virginia. The collections were made at 687 different points, or collecting stations. The living insects were placed on moist cloth in glass jars covered with cheesecloth. When necessary the jars were packed in ice. The different types of pupae were isolated in vials for the emergence of adults. Special attention was given to selecting recently transformed pupae with the larval cast skin, consisting of the head capsule, mouth parts and anal ring attached. It was thus possible to obtain the characters of the larva, pupa, cocoon and adult. Adult female flies were collected by sweeping with an insect net or they were captured while they were actually feeding on a turkey.

DISTRIBUTION.—Females of *Simulium nigroparvum*, collected while feeding on turkeys, were obtained from a considerable area, the extent of which is indicated by the following collecting points: On the north, Warm Springs, Bath County; on the east, Tunstall, New Kent County; on the south, Boones Mill, Franklin County; on the west Grahams Forge, Wythe County. Adults of *S. slossonae* were taken only in New Kent County.

* Specimens of *Simulium nigroparvum* were determined by C. R. Twinn, Department of Agriculture, Ottawa, Canada, and of *S. slossonae* by Dr. Alan Stone of the U. S. National Museum.

The larvae and pupae of *Simulium nigroparvum* were taken in 23 counties, of which 15 were west of the Blue Ridge, 7 in the foothills and 1 in the Tidewater. They were found, often in large numbers, in the following streams: James, Roanoke, New, Little, Shenandoah (particularly the middle and north forks), Jackson, Cow Pasture, Calf Pasture, Clinch and Rivanna rivers; and Reed, Big Walker and Little Walker creeks. Very few were collected in medium sized streams (averaging 8 to 15 feet wide and 1 foot deep) such as Back Creek, near Dublin; Sinking Creek, near Newport; Linville Creek, near Broadway; and upper North Anna River. Most of the collections made in the large streams east of the foothills, where the flow of the water is sluggish, failed to yield the species. However, a few specimens were taken in the James River just above Richmond, which was the most easterly point at which they were found. Here the river formed rapids, and water willow growing among rocks was abundant.

LARVAL HABITAT OF *Simulium nigroparvum*.—Large streams with rather flat, rocky bottoms and containing some plant growth are most suitable as breeding places for *Simulium nigroparvum*. The immature stages are found in streams with a flow of 4 or 5 feet per second. Although larvae and pupae attach themselves to rocks, moss and other objects, they are most often found attached to the water willow, *Dianthera americana* L., where this plant has been submerged by the current to a depth of 4 to 10 inches. An ideal habitat may be described as one in which there is a swift current flowing around the edges of, or in open channels through, vegetation growing among rocks. The larvae and pupae were abundant near the surface of the water but were taken at all depths up to 2 feet. A few larvae were taken in small streams, such as Back Creek, Pulaski County; Sinking Creek, Giles County; Linville Creek, Rockingham County; and upper North Anna River, Louisa County. They were practically absent at the mouths of such streams, even when the large streams into which the small streams emptied were densely populated.

Immature stages of *Simulium nigroparvum* were collected in streams from early April until November, but were scarce in early and late season. The period of greatest abundance was late June to September. In 1936, mature larvae and a few pupae were taken in Reed Creek on April 26, and pupae were plentiful on May 5. In 1937, a few larvae without histoblasts were taken in Reed Creek on April 2; and pupae were collected in Big Walker, near Poplar Hill, on April 13 and in Little River, at Snowville, on May 8. In the same year, 50 per cent of the insects collected on May 13 in Reed Creek at Grahams Forge had already transformed to adults. On April 14, 1938, mature larvae were taken in Little River at Snowville, and larvae and pupae were taken in Reed Creek at Grahams Forge. Few were found in the fall as late as middle October and early November. Some were found in Reed Creek on November 2 and in Big Walker Creek on November 6 in 1936; but none on November 1, 1937, or on November 2, 1938. The last pupa in 1938 was taken on October 20. *S. nigroparvum* probably passes the winter as an egg or immature larva.

The larvae and pupae of *Simulium slossonae* have not been taken by the author, and nothing is known by him of the habitat of the larvae of this species.

SOME HABITS OF FEMALE BLACKFLIES WHICH FEED ON TURKEYS.—Adults of *Simulium nigroparvum* were collected in the field as early as May 13, at which time they were observed feeding on turkeys. In the fall they were seen swarming around turkeys or around a person's head as late as the first week in November, but no feeding was noted after October 10. The principal feeding period was from June to September, inclusive, the maximum feeding generally taking place in July and August.

Adults of *Simulium slossonae* were taken feeding on a turkey, August 1, 1937, and again, July 7, 1938. On both dates nearly all blackflies taken were of this species. Seven out of 8 taken feeding in 1937, and 42 out of 45 taken in 1938 were of this species.

In feeding, blackflies attach themselves securely in the region of the turkey's head and neck and, until fully fed, are not frightened by the presence or approach of a person. The females of *Simulium nigroparvum* generally swarm around the turkey's head in large numbers; but, at times, single individuals may appear

suddenly. They may also disappear suddenly. Where the insects go in their retreat was not determined. They were not found on the leaves of trees or undergrowth. On a few occasions they appeared to come out of the woods, and nearly always larger numbers swarmed around turkeys or men in the woods than in the open fields.

The flies required 2 or 3 minutes to engorge. As a rule, they were not noticeably blood thirsty. Often, when large numbers were swarming around a turkey's head, only a few were found feeding. However, as many as 12 flies were seen feeding on a turkey at one time. On one occasion just preceding a thunder shower, feeding flies were taken at an average of 1 per minute for an hour. It often happened when turkeys were taken out into the field that flies were present, but little or no feeding of flies on the turkeys took place.

Flies have been collected while feeding from 5:30 a.m. until 7:30 p.m. Generally most feeding was observed about the middle of the morning and the middle of the afternoon. Feeding activity was apparently influenced by humidity, atmospheric pressure and temperature. A marked increase in activity was noted when the relative humidity was high or during a period of low pressure. This is in accord with observations made by workers on mosquitoes, who explain that the insects have an inefficient mechanism for controlling loss of water, and therefore are greatly influenced by relative humidity. Feeding activity was greatest between 75 and 85 degrees F. and almost ceased at temperatures below 70 and above 90 degrees F.

Adults of *Simulium nigroparvum* may spread over a considerable area from their breeding quarters. They were taken in fairly large numbers at 10 miles and in small numbers at 15 miles from any known breeding place. The insects could be found almost anywhere within their range—in fields and in woods, in valleys and on mountains. Adults were taken in a net at the crest of Walker Mountain and feeding on a turkey on Bald Knob; the latter has an altitude of about 4,000 feet. Bald Knob is approximately 7 miles from New River, the nearest stream in which the larvae were abundant.

Efforts to induce adults of *Simulium nigroparvum* to feed on turkeys in cages were unsuccessful. Flies reared from pupae or collected in nets in the field were used in cages as follows: in tiny capsules, vials and test tubes taped to or held against the turkey's head; in glass or celluloid cylinders, 5 to 6 inches in diameter, fastened with black cheesecloth over the turkey's head; in large glass cages, 3 by 3 by 3 feet; and in cheesecloth cages, 4 by 4 by 3 feet and 6 by 6 by 5 feet. In the experiments with the large cages, a turkey was placed in a cage and flies were introduced. In an effort to induce flies to feed the conditions were varied. Tree limbs and weeds with foliage were introduced into the cage; floors of wood, soil and sod were provided; the floor and walls of cages were sprinkled with water to increase the humidity; the cages were placed in bright sunlight and in the shade, or were shaded with black cloth or tarpaulin sheets. White, red and yellow lights were tested to determine their effect upon the feeding of the flies in glass cylinder cages over the turkey's head. The number of flies introduced into cages ranged from 1 in capsules and vials to 600 or more in the largest cage. The temperature varied from about 65 to 95 degrees F., but was generally between 75 and 85 degrees F. Humidity readings were taken in only one series of tests, in which the large cages were used, and ranged from 66 to 71 per cent. Observations on the flies in the tests were made at different times from early morning to late afternoon, and some were made at night. In most cases the flies simply rested on the walls of the cages. They tended to collect on the side or top where the light was the brightest and showed no inclination to feed on the turkey.

SUMMARY.—This paper is a preliminary report of the two species of blackflies, *Simulium nigroparvum* and *S. slossonae*, as found feeding on turkeys in Virginia.

Over the mountainous area of Virginia, *Simulium nigroparvum* occurs in the larger rivers which have rather flat, rocky bottoms. The heaviest infestations have been observed where the water willow, *Dianthera americana*, was present, and where the current was 4 to 5 feet per second. Larvae, pupae, cocoons and adults have been taken in large numbers. Female adults were captured while feeding on turkeys.

Females of *Simulium slossonae* were

taken only in New Kent County. Adults have not been reared by the author, and at present the type of stream in which they breed is not known.

The female flies attached themselves to the head and neck region of the turkey. About 2 to 3 minutes were required to engorge. They bit any hour of the day from early morning to late afternoon. Most feeding was done when the humidity was relatively high, atmospheric pressure low, and when the temperature was 75 to 85 degrees F. Flies in captivity did not feed on turkeys.—4-1-39.

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Certain Aspects of the White-Fringed Beetle Problem

JOHN T. CREIGHTON,* *University of Florida, Gainesville*

The introduction into the United States of a new insect may attract little or much attention. In general, the publicity an insect receives is based upon its food habits. If it selects as its principal food crops of great economic importance, its notoriety is immediate and continuous; while, if the crop is non-economic, the species is doomed to comparative oblivion. Publicity is essential to align the citizenry for the necessary entomological activities that follow the introduction of injurious species. The populace and legislative leaders must have a sympathetic attitude concerning the many problems of research and control workers while these workers are attempting to determine methods whereby the ravages of a particular species may be reduced to a minimum.

The appearance of foreign insect species in one of the major economic crop areas of our nation immediately obligates all involved entomological organizations to foster a cooperative program directed at eventual control or eradication of the species. The intensity of the control-eradication efforts should be determined by the apparent or estimated economic importance of the species. The eradication efforts should not be abandoned or relaxed until it has been scientifically and practically proved that eradication is impractical. The history of the establishment and success in the United States of many of the most destructive introduced pests frequently is one of shortsightedness upon the part of legislative leaders and control operators.

Control-eradication procedures should usually follow in the footsteps of known research facts. However, control-eradication cannot always wait for research to lead the way. The intensity and speed of the activities required in a campiagn demand that in part the trial and error method must be employed. This procedure will inevitably result in some financial waste, but such waste is justifiable if the involved species is of great economic importance.

During the 1938 adult season of the white-fringed beetle the Bureau of Entomology and Plant Quarantine, U. S. Department of Agriculture, deemed it advisable to test the efficacy of the control operations that were being employed in the Florala, Alabama, area. In the opinion of the author, these tests are entirely justifiable and should be increased in scope; certainly never abolished. If properly handled they will act as an effective guide line which should result in the more economical handling of control methods.

The testing operations in the Florala, Ala., area, and observations in the Pensacola, Fla., Mobile, Ala., Gulfport, Miss., Laurel, Miss., and New Orleans, La., areas were continued from June 1 until September 10, 1938. Eight men trained in entomology and 20 laborers were used in these operations. The following pages record some of the results.

* From June 1, 1938, to September 20, 1938, the author was technical adviser to the Chief of the Bureau of Entomology and Plant Quarantine, U. S. Department of Agriculture, and assigned to the white-fringed beetle project of the Division of Domestic Quarantines.

HOST RELATIONSHIPS.—The white-fringed beetle, *Pantomorous* (*Naupactus*) *leucoloma* (Boh.), is a species that seems destined to reach a condition of almost complete polyphagy. The most recent host list of this insect contains 162 larval hosts and 120 adult hosts. These include both wild and cultivated plants.

The host range of a species is important from the standpoint of the systematic as well as economic distribution.

The author (1938) has made detailed studies during the past 4 years relative to insect diet and insect abundance, and also the relationship between the chemical composition of the soil and insect populations. Feeding experiments indicated that diet deficiency affects the general vitality of certain insects and the prolificacy of females. This fact may eventually result in dietary reproductive inhibition. Tests made by the author indicate that elemental deficiency or variation may likewise materially affect the prolificacy of females. The so-called trace elements were tested. The mortality of the immature insects was increased when fed upon deficient host material. Continued feeding upon deficient plants resulted in elemental castration of the females.

Before and after enlistment in the campaign against the white-fringed beetle, the author could not refrain from thinking in terms of the effect of diet, soil chemicals and soil types upon the population of this species. Soil types are frequently important in the normal distribution of a species. They do not always play as important and clear-cut a part in the economic distribution of injurious species. A survey of the New Orleans, Laurel, Pensacola and Florala areas indicates a diversity of soil types, with the white-fringed beetle population varying in these areas. These soil types to some degree determine the vegetation of a given area. In turn the vegetation determines the possibility of a given species gaining and maintaining a foothold. The white-fringed beetle approaching a condition of almost complete polyphagy is therefore assured of a systematic distribution. However, the availability of key reproductive material is likely the determining factor in the economic distribution.

Population counts made during the emergence period of 1938 indicate that the population is not so intense in the New Orleans and Pensacola areas as in the Florala area; this condition existing in spite of the fact that the New Orleans infestation is doubtless much older than the one at Florala. There are possibly many limiting factors affecting the biotic potential of *Pantomorous* (*Naupactus*) *leucoloma* in New Orleans and Pensacola. However, there is no factor that plays a greater part in the economic abundance than does the type and availability of host material.

In the Florala area the host set-up is entirely different. It seems that the economic abundance of the species may be attributed in great part to the quantity of cultivated crops that may be designated as key reproductive host material. Such crops as peanuts and cotton are apparently the determining factor in the abundance that now occurs in this area.

Control-eradication attempts must of necessity involve a careful consideration of a reduction or elimination of the key reproductive hosts. Observations revealed the spotted nature of complete crop destruction and the annual variation or movement of the spots of severest infestation. For example, in 1937 the crops in certain areas of farms were a complete loss, while crops on the same areas in 1938 were apparently in good condition. The areas where greatest crop destruction occurred in 1938 were usually those that had been occupied in 1937 by peanuts or cotton or were adjacent to such areas. Farm surveys were instituted under the author's direction during the 1938 season in an effort to study the effect of crops upon future damage.

Entomologists enjoy the freedom that is permitted in visualizing the eventual economic importance of a species. The author has devoted many hours to such a consideration of the white-fringed beetle. This consideration has involved the entire United States with special emphasis upon the southern states, including Florida.

When one is within the area where the greatest population of a species occurs there is a natural tendency to form a premature opinion concerning the future economic importance of the pest. This has been uniformly true since the first introduction of a foreign species occurred. Rarely has a pest lived up to its advance notices. This has been due in part to limiting factors that were not considered

and in part to the scientific worker's ability to detect the weak spot in the insect's make-up by careful life history and habit studies.

A visit to the center of the Florala, Ala., white-fringed beetle area will invariably cause the layman and even the scientific worker to overestimate this insect's potential power. A longer stay in this area, during which time one considers the spotted nature of the severest infestations, and then subsequent visits to the Pensacola, Fla., and New Orleans, La., areas will frequently force a reconsideration of the original estimate.

WOODLAND INFESTATIONS.—There are those who maintain that the infestations that are present in certain woodland areas in the Florala district are just as heavy as those in the cultivated areas. Counts made in these areas fail to substantiate such contentions. It would be contrary to the past history of species in general for this to be true. The availability of key reproductive host material would naturally be reduced to a minimum in the woodlands. The author is of the opinion that any heavy infestations that may now exist in these wooded areas are due to the annual adult migration of well fed, strong reproductive females from nearby cultivated areas that have been cropped to key reproductive hosts.

The question of the effect of hosts upon the population was discussed with some of the Florala research staff, and the author understands that certain tests were made with some hosts which resulted in conclusions that are necessarily of an indefinite character. Research data accumulated over a 3- to 5-year period should prove of great value.

Some workers feel that the woodlands present one of the greatest problems in a vigorous control campaign. It would seem that in this respect the control forces in the Florala area have been smiled upon by fate, as the majority of the woodland tracts in that district have been thoroughly raped by lumber companies. This should facilitate control efforts.

LARVAL POPULATIONS IN THE SOIL.—Judged by the number of adults that emerged from the Florala plots and the insect's reproductive potential the number of larvae per acre in the heaviest infested areas must run into hundreds of thousands.

The author considered this point from the standpoint of Florida crops. Observation made in the Florala area revealed that in many cases the soil might be rather heavily infested with larvae without any loss in the stand of peanuts, cotton, corn and similar crops. However, it seems that when the larval population reaches a certain point the crop loss is severe. This factor will mean a great deal in so far as particular regions and crops are concerned.

In Florida, crop production is rather specialized in most districts. The potato, citrus, sugar cane, tobacco, cotton and the major vegetable districts are rather sharply defined. The present known infested area of Florida is a cotton, peanut and corn area. This crop set-up is apparently ideal for the population increase of the beetle.

Let us assume that the beetle will eventually become generally distributed throughout Florida; what may the growers in other areas expect? If the insect becomes established in the Hastings potato district, it might threaten the entire potato industry in that area or it may prove to be a pest of minor importance; its success or failure depending upon its ability to build up a population in this new environment. It is certainly true that, to become an extremely important pest in this area, the beetle will never have to reach the populations that now exist in the Florala area. This is due to the fact that the crop is a root crop and any attack upon the tubers will result in a lowering of the grade, or culling. A population increase that would result in a larval infestation one-half as great as that which occurred on the Show farm in Lockhart, Ala., would doubtless result in a loss of 85 to 95 per cent of the potato crop.

The Hastings, Fla., potato crop is a winter and early spring crop with the harvest occurring in March and April. The majority of the land is then planted to corn. Therefore, when the adult beetles would emerge the available host material would not be potato foliage, but corn and native grasses. It is believed that the biotic potential is lowered when the insects feed upon grass or grass crops. Therefore, the insect might never become of great economic importance in such an area.

In the case of citrus, there would be two determining factors. Tests have indicated that the adult will feed upon citrus foliage. The fecundity of the females when fed a straight citrus diet over a period of years may influence the population build-up and thereby the economic importance on this crop. The annual variation or movement of the areas of severest infestation would favor a definite resistance by all tree crops, including citrus.

The aforementioned factors would also play an important part in the celery and vegetable districts.

TRAP CROPS.—The white-fringed adult beetle has certain food preferences. The advisability of attempting the use of these as trap crops is debatable. There are several factors that might be mentioned that will doubtless discourage their use.

During the 1938 season it was found rather difficult to keep poison dusts on the key reproductive plants because of heavy rains. The crops used as trap crops if consumed by the adults will doubtless increase the biotic potential. Therefore, it would seem illogical to plant these crops in the areas where the beetle population

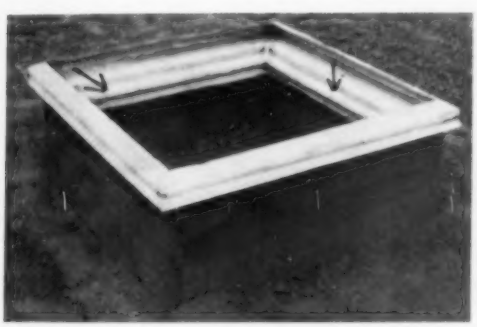

FIG. 1.—Barrier no. 1. Effective metal barrier.

is low; for example, in the New Orleans or Pensacola areas.

BARRIERS.—The white-fringed beetle's inability to fly makes the study of barriers a very important one. There seems to be a very definite migratory period during the adult season. There are doubtless several contributing factors, such as oviposition urge, cloudiness, temperature, humidity and rainfall.

BARRIER TRENCHES.—During the 1937 and 1938 adult seasons, two types of barrier trenches were employed in an effort to prevent migration. One of these is commonly termed the outside barrier ditch and was constructed around the periphery of major infestation areas. It was a ditch 16 inches in width with 10.5-inch vertical side walls. The other is termed the field ditch. This ditch was 12 inches in width and 10 inches deep. Fig. 12 illustrates this type of ditch constructed around a field where crop de-

FIG. 2.—Barrier no. 1. Detailed view.

struction was approximately 80 per cent. Methods of construction of these ditches is given in Bulletin No. E420 of the Bureau of Entomology and Plant Quarantine, U. S. Department of Agriculture (Young *et al.* 1938).

The author conducted numerous tests relative to barrier ditch efficiency. It was found that the field ditch and the barrier ditch were exceedingly effective during dry sunny or cloudy weather. Their effectiveness was as high as 98 to 100 per cent during such periods. Summer rains in the Florala area are frequently followed by 12 to 72 hours of cloudy weather. One of the most typical characteristics of the beetle is the tendency to migrate relatively long distances and in large numbers during cloudy weather. This migration invariably comes at times when the rain has packed the soil on the sides of the ditches and rendered them ineffective as a barrier. Therefore, they may be listed as practically worthless.

METAL BARRIERS.—The author designed and had constructed 12 metal barriers. These were made from 29-gauge galvanized tight-coat sheets cold rolled after coating; they were twelve inches wide. This type of material was selected as the surface is extremely smooth. However, unless they are protected, the weather will reduce this value. All of the

barriers had one thing in common. That was a 1½ to 2 inch semicircular turn made in the metal. Two of the 12 barriers were

FIG. 3.—Barrier no. 2. Effective metal barrier.

100 per cent effective in the tests conducted. These are illustrated in figs. 1, 2, 3 and 4. The structural character that apparently renders these barriers effective is the turn in the metal, which is shown by arrows in the illustrations. Figs. 5 and 6 illustrate the methods of construction.

The author feels that it is feasible and logical to use these as a substitute for the ineffective ditches. The use of these in nurseries and around incipient infesta-

FIG. 4.—Barrier no. 2. Detailed view.

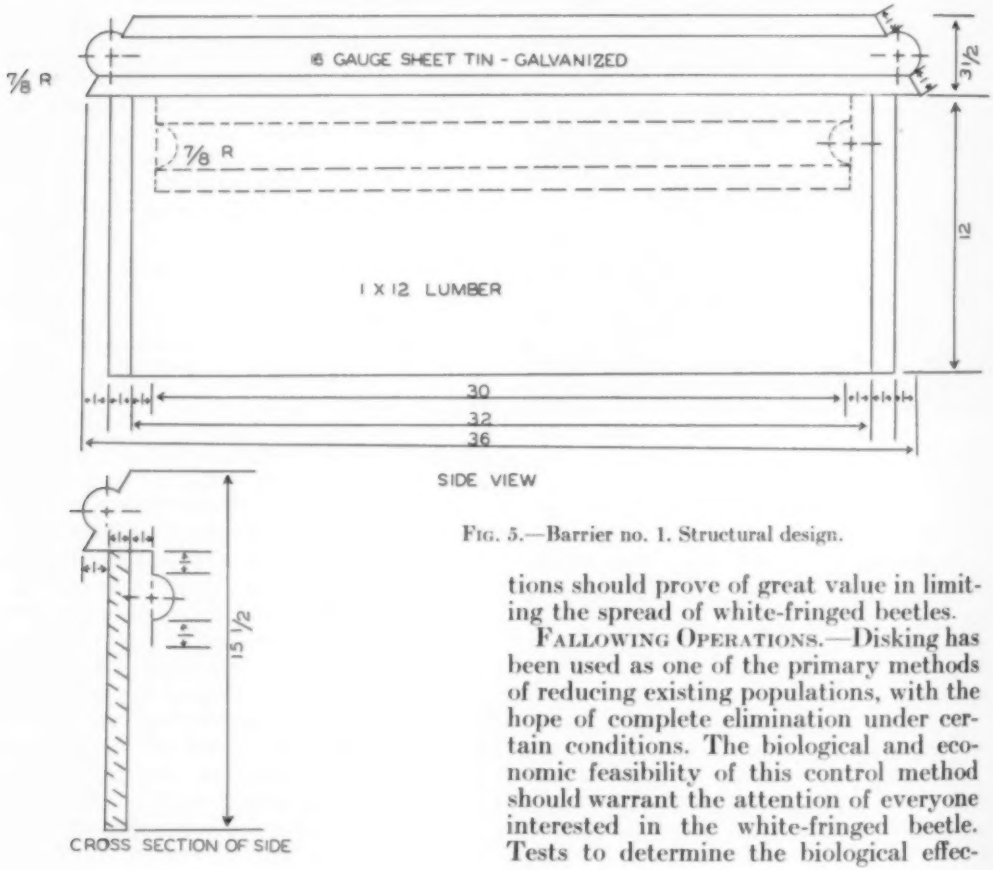

FIG. 5.—Barrier no. 1. Structural design.

tions should prove of great value in limiting the spread of white-fringed beetles.

FALLOWING OPERATIONS.—Disking has been used as one of the primary methods of reducing existing populations, with the hope of complete elimination under certain conditions. The biological and economic feasibility of this control method should warrant the attention of everyone interested in the white-fringed beetle. Tests to determine the biological effec-

tiveness of this method, together with the most suitable disking interval were instituted under the writer's supervision early in the month of July, 1938. These tests were continued until September 10, 1938. A considerable amount of data was accumulated, during these 2 months, that has revealed certain things of possible scientific and practical value. However, the author feels that it would be extremely unwise to make very emphatic statements concerning results that might be expected from disking because the contemplated data have not been completed and the testing period was too short. The more intimately acquainted one becomes with the white-fringed beetle, the more one realizes the inadvisability of hasty conclusions. Nevertheless, in the interest of the future control activities it would seem imperative that every worker list whatever conclusions he has drawn, regardless of the incompleteness of the data. In doing this, all other workers must appreciate the fact that these conclusions because of their very nature will in many cases prove to be false assumptions that have been made upon reviewing limited data.

DISKED TEST PLOTS.—Eight test plots were established near Lockhart, Ala., which is in the center of the infested districts. These plots were located on the Show farm (property 625) in Covington County. The tract selected contains 84 acres and was heavily infested throughout. It was broken into eight plots that were numbered consecutively from 1 to 8. Plots 1 to 7, inclusive, contained 10 acres each. Plot 8 contained approximately 14 acres.

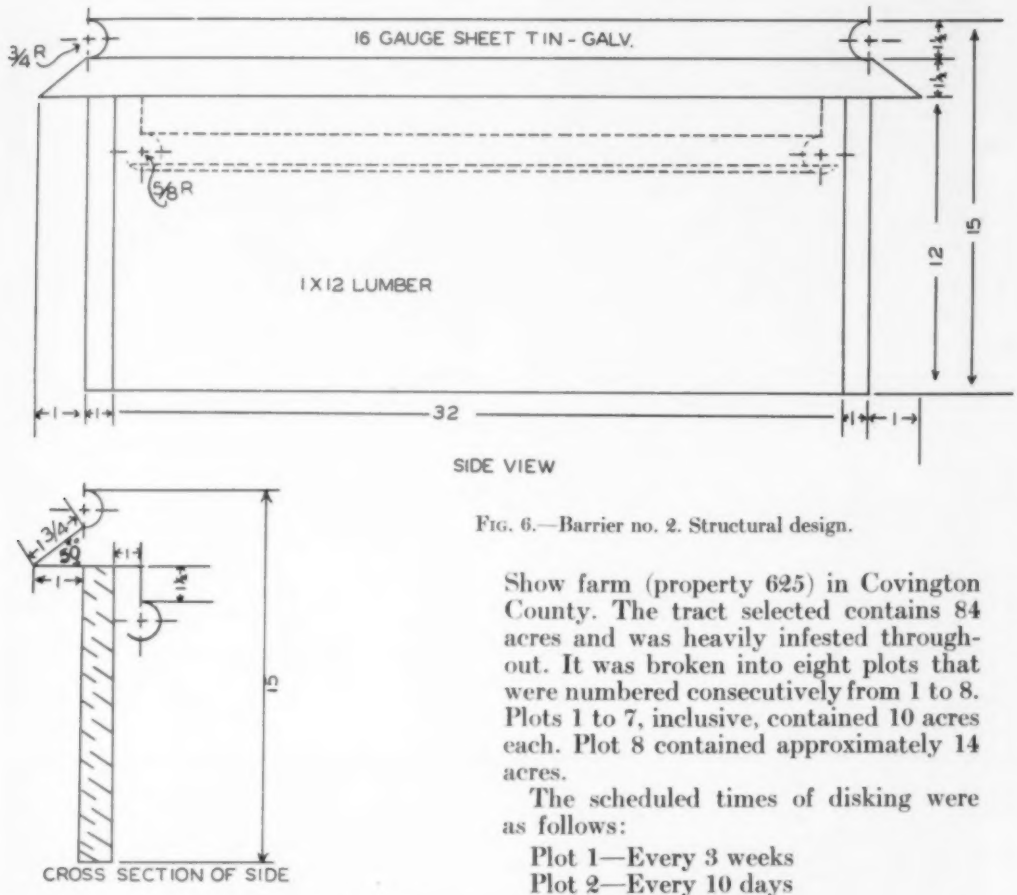

FIG. 6.—Barrier no. 2. Structural design.

The scheduled times of disking were as follows:

Plot 1—Every 3 weeks
Plot 2—Every 10 days
Plot 3—Every week
Plot 4—Every 2 weeks
Plot 5—Every 4 weeks
Plot 6—Every 6 weeks
Plot 7—Check—left untreated (fig. 9)
Plot 8—Dusted with calcium arsenate

Rains seriously interfered with scheduled disking operations.

The outside type of barrier ditch was constructed around the entire tract and between the plots, fig. 7. Post holes were dug in the bottom of the ditches at intervals of 12 feet.

The following observations were made:

1. Migration day and night.
2. Adult mortality due to heat and starvation.
3. Adult populations in barrier ditches, between terraces and on terraces.
4. Reproductive ability.
5. Poison effectiveness.

FIG. 7.—Outside barrier trench.

The disked plots were treated at scheduled intervals. In order to maintain the plots completely nude of vegetation, fig. 8, it required frequent treatment even during periods of drought. During rainy periods such as were experienced during the height of adult emergence and migration treatment was found to be practically impossible. However, the existing vegetation was native weeds and grasses, figs. 9 and 10. The barrier ditches which were used are illustrated in fig. 7. Population counts were made daily, fig. 10, in each plot, the record of living and dead insects per acre being determined. Field cages, fig. 11, were employed on all plots to determine the length of life and fecundity of the females. Adults were removed daily from each plot and retained in the laboratory on food taken from their particular plot. Oviposition data were recorded. Migration tests were made to determine the distance an insect can travel when soil is in a dust mulch condition.

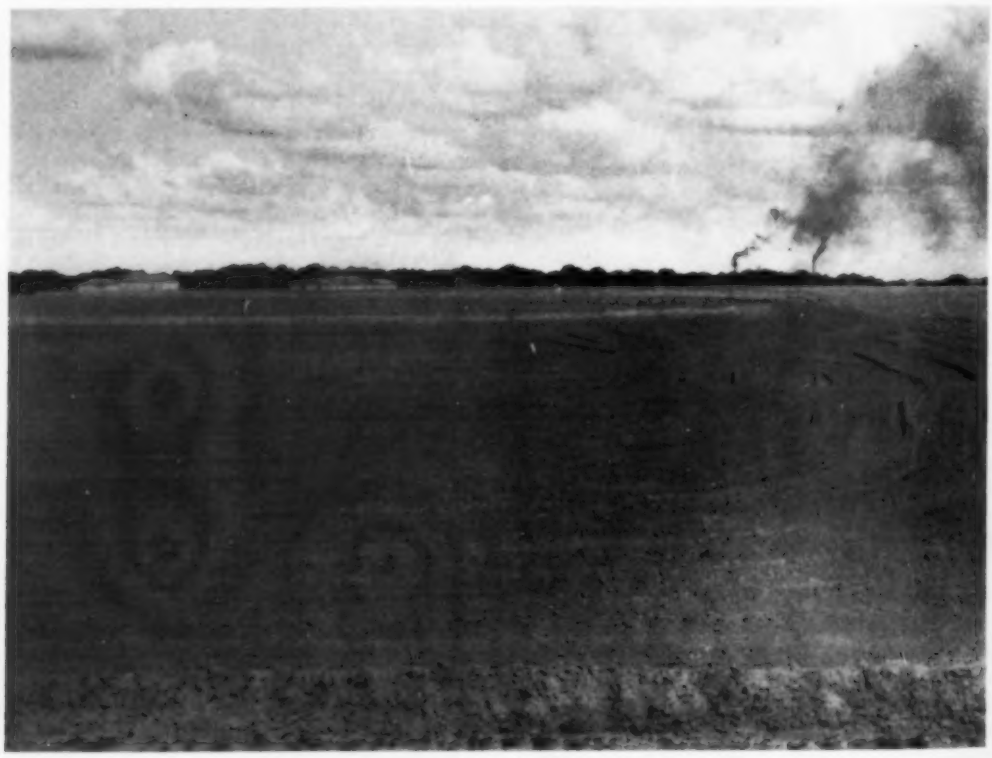

FIG. 8.—Clean fallowing in the experimental plots.

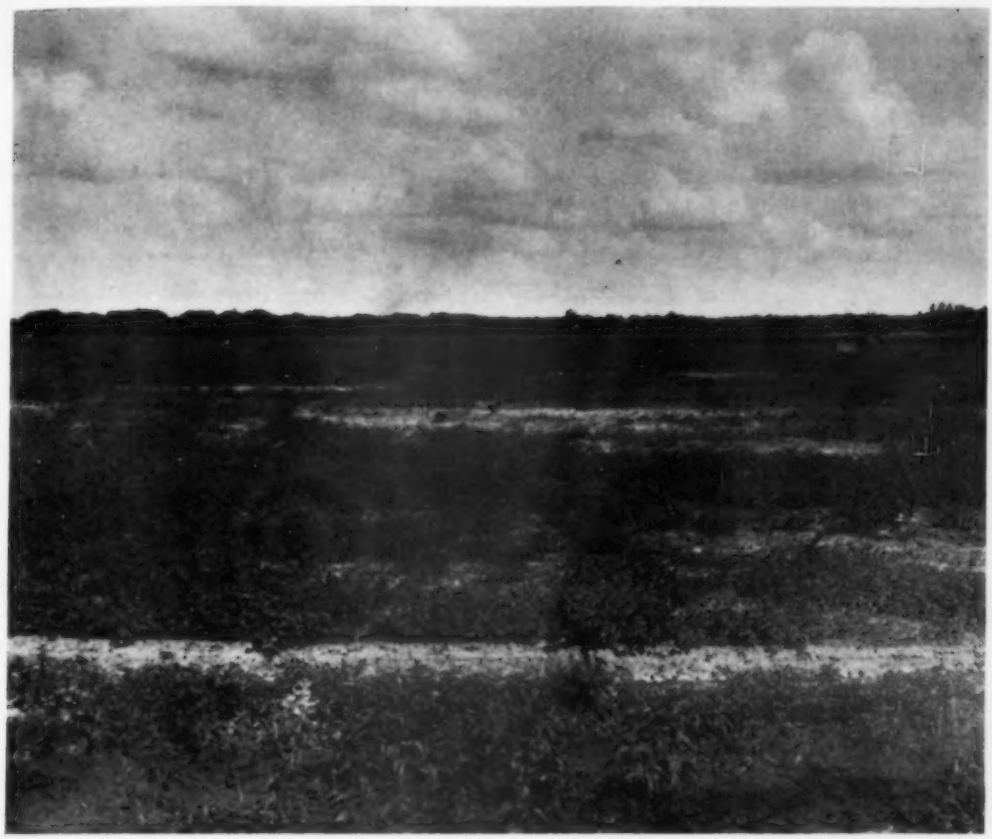

FIG. 9.—Check plot. Disked June, 1938.

The data accumulated during the 2-months testing period have disclosed several things of striking significance. These are as follows:

1. It is inadvisable for one to rely upon disking as an immediate or 1- to two-year method of extermination for the white-fringed beetle. The author bases this statement upon the fact that even those adults in plot 3 (disked weekly) were capable of ovipositing some virile eggs, after consuming the vegetation existing in this plot.

FIG. 10.—Population counting by testing operator.

FIG. 11.—Field cages on experimental plots.

2. It would seem inadvisable to institute intensive disking operations prior to June 25. The maximum adult activity in the Florala district during 1938 was from July 12 to August 20.

3. The ineffectiveness of the barrier ditches will necessitate the use of metal barriers where barriers are needed, fig. 12.

4. The application of dusts should be placed in the hands of experienced dust operators if such an operation is to be economical, or effective.

5. Adult mortality was high during clear, dry weather when the soil was maintained in a dust mulch condition. Migration was reduced.

FIG. 12.—Field trench surrounding corn planting.

CONCLUSIONS FROM THE DISKING TESTS.—The fact that adults emerging in plot 3 (disked weekly) were capable of ovipositing virile eggs has an immediate discouraging effect. Likewise it is rather upsetting to the disking supporters to realize that emergence of the adults appears to be linked closely with rain periods and that during the summer rain periods disking is out of the question. This inevitably results in a period of reproduction freedom for the beetle, such freedom tending to inhibit the possibility of total eradication.

The author feels that it would be advisable to consider the matter in a different manner. Let us assume that we construct a metal barrier around this plot in May. If this plot were freed of cultivated crops and not cultivated for a period of 5 years, there would doubtless be a marked decrease in the population of the white-fringed beetle. On the other hand, if this plot were plowed on July 1 and disked on July 16 each year, and then left untreated, the population decrease might be greater. It must always be realized that the insect population is based both upon the availability of host material and the availability of key reproductive host material. It is just within the realm of possibility that the elimination of key reproductive host material over a period of several years might be an economical method of reducing the population to a point of vulnerability.

The data accumulated revealed that the insects from plot 3 (disked weekly) were capable of ovipositing. Likewise, it revealed that as the disking interval was increased to 10 days, 2 weeks, 3 weeks, 4 weeks, etc., so did the oviposition apparently increase. It was found however that the increase in oviposition ability was relatively slight from the 1-week to the 4-week plot adults. The author has stated that the oviposition ability exists regardless of the nature of the disking; however he has not stated that the prolificacy of the female is left undisturbed nor has he said that the percentage of virile eggs produced and the length of life of the adult are left unchanged. All of these factors will have a marked influence upon the future populations. That weekly disking is a biologically effective method of reducing white-fringed beetle populations cannot be questioned, but whether it is an economical method of control can be determined only by the administrative officers in charge. The desirability of using the weekly method in preference to the 2- or 4-week method is very doubtful, as tests indicate that they give approximately the same results. Soil populations are reduced by disking, and in eradication attempts this cultural method must be considered.

In tests that the author has made with other species it has been proved that dietary reproductive suppression or inhibition may not occur until after the insect has been subjected to specific diet conditions for a period of 3 to 7 broods. It is entirely possible that the biotic potential of those insects existing in 1938 in plots 1, 2, 3 and 4 upon reaching adulthood will be even lower than the biotic potential of the adults that produced them, assuming that the availability of key reproductive host material is again reduced to a minimum during the 1939 adult season.

POISON DUSTS.—The research staff of the Bureau of Entomology and Plant Quarantine indicated the extreme suceptibility of the white-fringed beetle to arsenical poison following studies which were made during the summer of 1937.

The control division employed calcium arsenate dusting of cultivated crops and wild plants during the summer of 1938 in an effort to reduce the beetle population. The Rachel farm (property 203) in Glendale, Fla., was used as a test area. Rachel's cotton crop was given rather careful attention. The dusting operations were done carefully and at the necessary intervals.

The testing operators made numerous and careful checks in an effort to determine the effectiveness of these operations.

The results obtained may be summarized as follows:

1. The dusting operations were usually efficient.

2. There was no precipitation between June 28 and July 10. From July 10 through July 31 there were 16 days when there was noticeable precipitation; or 16 rainy days during the last 21 days in July. During these 16 out of the last 21 days in July there was a total precipitation of approximately 9.5 inches.

3. Following the initial July precipitation on the tenth, adult emergence greatly increased. Within a period of 48 to 72 hours the severely infested areas were heavily populated with adult insects.

4. Maximum adult activity continued from July 12 through August 20; and population counts show a severe tapering after August 20.

5. From August 1 through August 20, 1938, there were 6 days out of the 20 when there was noticeable precipitation. During this 20-day period there was a total precipitation of only 2.06 inches; and only in two instances did precipitation occur on 2 consecutive days.

6. Treated cotton was toxic to the adult beetles; the lethal effect varying directly with the degree of precipitation and the length of the precipitation period.

7. The numerous counts which were made revealed an average lethal effect during the July 10–31 period of 30.9 per cent; and a lethal effect of 98.2 per cent during the August 1–20 period.

CONCLUSIONS FROM THE POISON DUST TESTS.—Results of the poison dust tests seem to justify the following conclusions.

1. Calcium arsenate can be successfully used in the reduction of existing populations.

2. Unfortunately, adult emergence seems closely linked with precipitation, which introduces a limiting factor into this method of population reduction.

3. Continuous rains greatly reduce the lethal effect, while there is only a slight reduction during intermittent rains.

4. Slight precipitation may somewhat increase the toxicity of the poison, as the adults have been observed drinking drops of water containing the arsenical.

5. Results indicate the importance of a study of adhesive agents.

THE USE OF WEED KILLERS.—The 1938 season saw the use of oil in two forms

FIG. 13.—Tree banded with tanglefoot.

in an effort to reduce the quantity of available host material. These oils were used in areas where disking and dusting were non-feasible. The crude oil used during the early part of the season was discarded because of the cost and other undesirable features. Substituted for this was an emulsion containing oil, sodium arsenite and caustic soda. The testing division attempted to test the toxicity of these materials to adult white-fringed beetles; also their effectiveness as weed or plant killers. The fact that the initial oil was discarded eliminates any necessity for the discussion of this material by the writer.

The results in the use of the oil emulsion may be summarized as follows:

1. The initial kill of native weeds and grasses usually approached 98 per cent.

2. The spray was directly and immediately toxic to approximately 35 per cent of the beetles which were coated.

3. The average minimum length of complete effectiveness as a distroyer of weeds and grasses was 5 days.

4. The return growth of grasses exceeded that of weeds.

5. Moderate weed effectiveness was maintained for a period of 8 days.

6. The death rate was relatively high for white-fringed beetle adults maintained on sprayed foliage during the 8 days subsequent to spraying.

CONCLUSIONS FROM THE WEED KILLER TESTS.—Results of the tests with weed killers seem to warrant the following conclusions:

1. For the weed killer to be completely efficient will necessitate applications at 5-day intervals.

2. Applications at 5- to 15-day intervals are of some value as weed killers, but would not be a recommended procedure if the project leaders are thinking in terms of extermination of the white-fringed beetle.

3. The economic feasibility of this spray material is a matter that will have to be determined by the administrative officers in charge.

TREE BANDING.—Tests were begun in July, 1938, in an effort to determine the effectiveness of tanglefoot barriers when used on pecan trees.

In preparing the bands, fig. 13, an instrument was used to remove the rough bark and create a smooth band approximately 3½ to 4 inches in width. A heavy coat of tanglefoot was then applied. The height of the bands were varied from 2 to 8 feet. The bands were checked and improved in condition at regular intervals.

1. The adult white-fringed beetle will eat the foliage of pecan trees and is capable of depositing some virile eggs when fed a straight pecan diet.

2. The adults will ascend pecan trees.

3. A fresh tanglefoot band 3½ inches in width is an effective barrier.

4. The fresh band apparently has some repellent value; this might suggest possible investigations relative to repellents.

5. The length of time that the barrier will remain 100 per cent effective will depend upon the tree's nearness to the roads, the stirring of the soil in which the tree is growing and the climatic conditions.

TESTS IN FOREST AREAS.—A forest tract was selected in Covington County, Ala., for testing the effectiveness of control measures for the white-fringed beetle. Four 5 acre plots were established. The tract was a piney woods type of forest area fig. 14, with an undergrowth consisting of many of the wild host plants of

the beetle. Plots 1, 2 and 3 were cleaned with the exception of preferred wild hosts. Plot 4 was left intact. Each plot was inoculated with beetles, each receiving the same number.

In plot 1 the hosts were sprayed with Paris green and rosin fish-oil soap sticker. Plot 2 was left as a check. Plot 3 was

FIG. 14.—Forest plots.

treated with the oil emulsion containing sodium arsenite. All plots were surrounded by the outside type barrier ditches.

The following results were observed:

1. Because the testing division was unable to obtain the tract of land before the latter part of the 1938 adult season, proper tests could not be made. This particular phase of the testing work should be continued.

2. It was found that after 5,000 adults had been liberated in each plot they were extremely difficult to retake even though the greater part of the surface vegetation has been removed. This fact illustrates emphatically the degree to which a new infestation would have to advance before scout inspection could possibly reveal its presence.

GENERAL OBSERVATIONS.—One of the most important general observations that the author noted concerning *Pantomorous* (*Naupactus*) *leucoloma* (Boh.) was the striking relationship between water and this species. This link between the adult beetle's activities and water appeared in different ways. Some of these have already been mentioned. It might be well to repeat them here.

1. The eventual peak adult emergence is apparently tied in with precipitation.

2. The degree of migratory activity is determined by precipitation periods followed by cloudy weather.

3. Numbers of adults may be washed about in ditches covered in 5 to 6 inches of mud for several days without complete mortality resulting. If released, many of the females are capable of ovipositing virile eggs.

4. The adults will rest on plants and drink water, even that which contains arsenicals.

5. Precipitation markedly affects the geotropic response of this species. During fair, hot, dry weather the adult remains relatively close to or on the ground except

when feeding, thereby showing a strong positive geotropism. Following heavy rain periods this tropic response is greatly altered and the insect exhibits a slight negative response. This negative response usually occurs during cloudy periods following rain. The beetles during this type of period have been observed on top of small buildings and in the top of rather tall trees. The author considers this peculiar reaction of more than common importance in so far as quarantine and control activities are concerned. This attitude is assumed because it is felt that the two major ways in which this species has been spread within the boundaries of the United States have been by the movement of nursery stock and of trains. Spread of the white-fringed beetle by trains seems so common as almost to encourage the use of the common name "railroad beetle" when referring to this species. It is doubtless during the time that this insect's geotropic responses are upset that the greatest possibility of spread by train movement occurs. Careful attention to all main lines and sidetracks at that time might be highly beneficial. Possibly metal barriers might be employed.—4-1-39.

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A Survey of Field Infestations of Insects Attacking Corn in the Ear in South Carolina*

O. L. CARTWRIGHT, *South Carolina Experiment Station, Clemson*

The purpose of this brief paper is to call attention to a serious unsolved problem which confronts South Carolina and other cotton states. This group of states produces almost exactly 20 per cent of the corn grown in the United States, in round numbers nearly 500,000,000 bushels annually. As we know, a considerable part of this is damaged and destroyed by insects in storage. We know, too, that infestations by many so-called storage pests start in the field before the crop is harvested.

To obtain information regarding this field infestation in South Carolina, a preharvest field examination was made during the 1938 season. With only two men available to make the survey and time for the study limited between the maturing and harvesting of the corn, it was necessary to confine the counts to 100 ears in each of two fields, in a few cases three fields, in each county, an examination of 10,000 ears for the entire state. Except in the case of the corn ear worm, *Heliothis obsoleta* (F.),† presence of the insect in the ear was considered infestation. Infestations found are shown in figs. 1–6.

LOCATION AND DEGREE OF INFESTATIONS.—The first map, fig. 1, shows the approximate location of the field counts

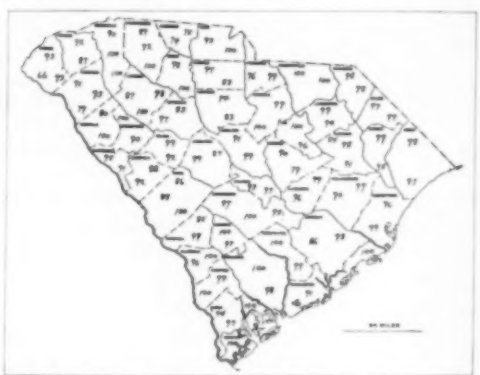

FIG. 1.—Per cent of ears of corn infested by the corn ear worm in South Carolina counties before harvest, 1938.

and the per cent of ears entered by the corn ear worm. A practically uniform and very high infestation averaging 93.82 per cent of the ears was found. The per cent of ears actually damaged by the corn ear worm is shown in fig. 2. Damage was usually confined to tip grains; however, a small amount of side injury is included in the figures presented.

* Technical Contribution No. 65 from the South Carolina Experiment Station, Clemson.
† Also *Heliothis armigera* (Hbn.). JOUR. ECON. ENT. 32 (4): 595.

In figs. 3 and 4, those counties which had 75 per cent or more infestation are shown in black. The first of these figures presents data on a flour beetle, *Cathartus cassiae* (Reiche); the other presents data found for the pink corn worm, *Pyroderces rileyi* Wlsm. These two insects prefer the coastal half of the state. Infestations of flour beetle and pink corn worm drop sharply in the Piedmont.

In the last two maps, figs. 5 and 6, black areas indicate over 50 per cent infestation; crossed lines, 25 to 50 per cent; and vertical lines, 10 to 25 per cent in-

FIG. 2.—Per cent of ears of corn damaged by the corn ear worm in South Carolina counties before harvest, 1938.

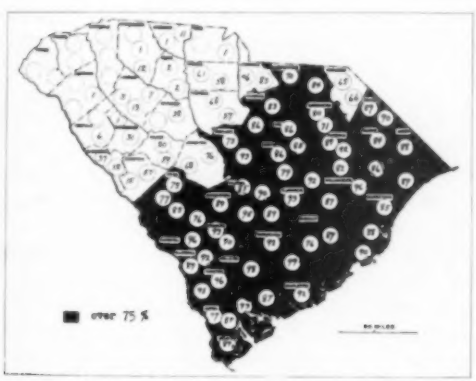

FIG. 3.—Per cent of ears of corn infested by flour beetle in South Carolina counties before harvest, 1938.

festation. The first of these two maps, fig. 5, presents infestation by the angoumois grain moth, *Sitotroga cerealella* (Oliv.). These data are undoubtedly much lower than actual infestation, since in a cursory field examination only ears showing the characteristic emergence holes made in the corn by the angoumois moth could be counted. Unless development of the moths had progressed to the forma-

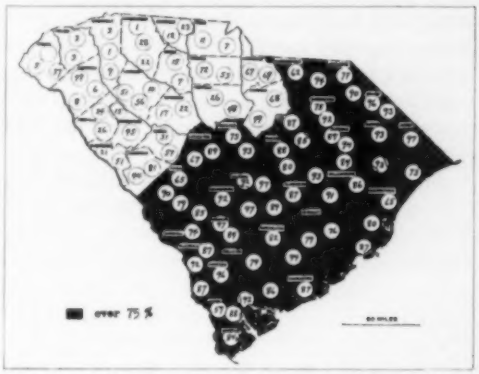

FIG. 4.—Per cent of ears of corn infested by the pink corn worm in South Carolina counties before harvest, 1938.

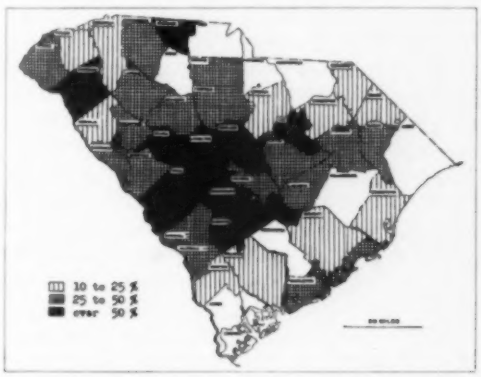

FIG. 5.—Per cent of ears of corn infested by the angoumois moth in South Carolina counties before harvest, 1938.

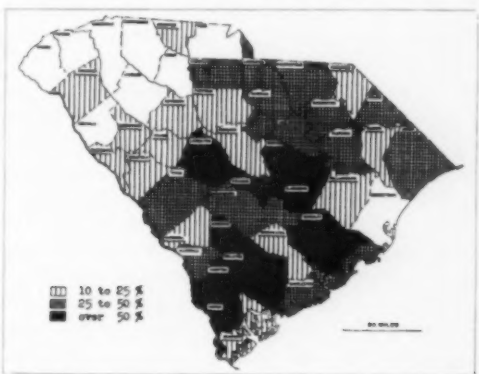

FIG. 6.—Per cent of ears of corn infested by the rice weevil in South Carolina counties before harvest, 1938.

tion of the "window stage," infested ears were passed as not infested. The last map, fig. 6, presents data on the second

of the two more important insects, the rice weevil, *Sitophilus oryzae* (L.). This serious stored corn pest is more active and injurious in the coastal half of the state than in other parts. If the data for the angoumois moth and the rice weevil are combined it will be seen that only two counties show infestations of less than 10 per cent.

SUMMARY.—A brief summary of the data on the 10,000 ears of corn examined in the field before harvest during 1938 reveals statewide averages as follows: Corn ear worm entrance, 93.82 per cent; corn ear worm damage, 84.14 per cent; flour beetle infestation, 57.71 per cent; pink corn worm infestation, 61.05 per cent; angoumois grain moth infestation, 31.04 per cent; and rice weevil infestation, 28.02 per cent.

Field infestations by these insects in other of the cotton states are unknown, but quite likely infestations equally great develop each season. The problem deserves more consideration than it has been accorded in the past.—3-13-39.

Cultural Practices and Their Influence Upon Citrus Pests

W. L. THOMPSON, *Citrus Experiment Station, Lake Alfred, Fla.*

During the past 6 years there has been a gradual but rather radical change in spray practices as well as other cultural methods in citrus production in Florida. The changes have tended to create conditions that are favorable for the development of scale insects although some of these effects have been accepted facts for years; for instance, it is well known that scales and rust mites increase more rapidly following Bordeaux than when no Bordeaux is applied. The generally accepted theory is that Bordeaux mixture prevents the development of entomogenous fungi which attack most of the citrus insects of economic importance. More recently precipitates of zinc and manganese have been added to the materials which are applied as a spray with resultant increases of scale insects. Zinc and manganese are applied for nutritional purposes while copper plays a dual role, being both a fungicidal and nutritional spray (Camp & Reuther 1937). All of the above named elements in their nutritional role can be applied as soil treatments, but quicker and more pronounced results are obtained with less material when they are applied as sprays. In Florida the term *inert residue* has been adopted to describe such sprays since the residues have no insecticidal value. *Inert residue* as used in this paper applies to such materials as hydrated lime and the precipitates of copper, zinc and manganese.

METHOD OF RECORDING.—Scale insect populations in the experiments referred to in this paper were recorded by the following method. All plots consisted of at least 10 trees unless otherwise indicated. Leaves were picked at random from the outside of the tree although all the leaves could not be strictly termed outside leaves.

In some of the earlier experiments 30 leaves were picked from each tree and the whole leaf examined for scale; later 50 leaves were collected and half leaves examined but during the last 2 years 100 leaves were collected per tree and quarter leaves examined. The leaves were examined for scales on the upper and lower surfaces, the position of each quarter being the same on all leaves and being next to the stem end of the leaf. When the leaves were collected they were put in paper bags and taken into the laboratory to be examined. The leaves were thoroughly mixed on a table, put back into the bag and drawn out at random in lots of 20. Each lot of 20 leaves was examined and the number of living scales recorded. A sufficient number of lots was examined (usually 10 lots from a sample of 1,000 leaves) until a constant average of living scales per leaf was reached. Only living scales have been considered in the population counts, although the scales attacked by fungi and other dead scales were also counted in many of the experiments. The scales were examined under the binocular microscope and the color used as an index of their condition, *i.e.*, dead or alive.

INFLUENCE OF INERT INGREDIENTS.—Purple scale, *Lepidosaphes beckii* (Newm.), and Florida red scale, *Chrysomphalus*

aonidum (L.), have increased to a marked degree where inert residues have been applied in sprays. The presence of inert residues in the various fungicidal and nutritional sprays appears to favor scale development to such an extent that it largely overshadows the effect of the entomogenous fungi.

In 1931 purple and Florida red scales increased very noticeably in two different plots of orange trees sprayed with four applications of hydrated lime at the rate of 10–100 and 20–100 (Thompson 1932). The following year the experiment was repeated with similar results. The results of these experiments indicated that inert residues might be a contributing factor in scale increases following Bordeaux sprays rather than the partial elimination of entomogenous fungi. Watson & Berger (1937) list five species of entomogenous fungi attacking purple scale and two species attacking Florida red scale. The most common species are the pink fungus, *Nectria diploa* B. & C., and the red-headed scale fungus, *Sphaerostilbe aurantiicola* B. & Br.) Petch, and are the scale fungi referred to in this paper. Further experimental work with copper sprays containing different amounts of residue varying from light to heavy seemed to bear out the results of the preliminary experiments. Bordeaux 6–6–100 was formerly recommended for the control of melanose, *Diaporthe (Phomopsis) citri* (Fawcett) Wolf, but Ruehle & Kuntz (1935) demonstrated that Bordeaux 3–3–100 gave commercial control in most seasons and that strength of Bordeaux is now being used instead of 6–6–100 because of the reduced scale build-up. About the time Bordeaux 3–3–100 came into use the so-called neutral coppers were introduced for the control of melanose and citrus scab, *Sphaceloma fawcettii* Jenkins. These materials are applied usually at the rate of 3 to 4 pounds per 100 gallons and contain 2 to 3 pounds less residue than is present in Bordeaux 3–3–100 and 8 to 9 pounds less than in Bordeaux 6–6–100. The scale build-up has been less marked following the neutral coppers than following Bordeaux 6–6–100 and on the average less than the buildup following Bordeaux 3–3–100, although the difference in the latter case has not been very marked.

INFLUENCE OF COPPER SPRAYS.—Since 1933 comparisons have been made of scale populations following the different copper sprays, and more recently zinc sprays, containing varying amounts of inert residues. With few exceptions the scale populations were more dense following the sprays with more residue than following the sprays with less residue. The comparisons between scale populations were made only in plots where the residue sprays were supplemented with the same kind of material, as oil emulsion, wettable sulfur or a spreader, and where the same follow-up sprays were used; therefore only a limited number of plots in any one experiment were considered. In each individual experiment the plots were divided on a basis of the amount of residue, a difference of 2 pounds of residue per 100 gallons being considered sufficiently large to justify a difference in classification. Results from 14 different experiments were studied, and 92 plots were used in 46 comparisons of varying amounts of residue. In only nine of the comparisons did the smaller amount of residue result in more scale than did the heavier residue and in seven of these nine cases the difference in residue was less than 3 pounds.

The scale fungi were not as abundant in the copper sprayed plots as in the checks or plots sprayed with lime sulfur and on the average a single application of Bordeaux 6–6–100 prevented the development of the scale fungi to a greater degree than Bordeaux 3–3–100 but not any more so than the neutral coppers that were being tested at that time. Where two copper sprays were applied within 6 to 8 weeks of each other the ratio of scale fungi to living scales was reduced to a minimum regardless of the kind or strength of the copper sprays, yet the scale population was higher where the heavier residue copper sprays were used. In a cooperative scab and scale experiment the red scale population was higher in six plots receiving a dormant Bordeaux 6–6–100 and a post-bloom Bordeaux 3–3–100 than in eight plots receiving a dormant neutral copper 4–100 and a post-bloom neutral copper 3–100. The scale fungi were scarce in all plots but more so where the neutral coppers were applied than where Bordeaux was used.

In table 1 are shown purple scale increases following copper sprays containing varying amounts of inert residue; also shown is the use of wettable sulfur as a

supplement for checking scale increases. The experiment has been conducted for 3 years, and each year the plots received a single application of the respective coppers in March or April with no follow-up spray for scale control. Although each plot consisted of only four trees the initial infestation was very low and uniform. Changes made in two plots are noted in the table. The scale counts were made in the usual method described previously.

Scale populations have been consistently higher in the plots receiving Bordeaux 6–6–100 plus wettable sulfur (plots 5 and 6) than in the one receiving Bordeaux 3–3–100 (plot 4). In 1936, plot 5 received Bordeaux 3–3–100 and the scale increase was on a par with the increase in plot 4, but in 1937, when the concentration was doubled, the scale population became denser than where the weaker Bordeaux was applied. During the past year the scale increase was more marked where basic copper was applied than in the Bordeaux 3–3–100 wettable sulfur plot. Over the 3-year period the most marked increase was in plot 7 which received Bordeaux 3–3–100 without wettable sulfur as a supplement. Scales also increased more noticeably during the past year in the check plots, but the trees were in a better growing condition than formerly, which may be responsible for the increase in those plots.

The ratio of scale fungi to living scales was much higher in the check plots than in the sprayed ones but the difference in per cent of living scales was not marked. In 1937, there was 138 per cent more scales and a lower ratio of scale fungi where Bordeaux 6–6–100 was used (plot 6) than where Bordeaux 3–3–100 was applied (plot 4); yet there was no significant difference in per cent of living scales. Where the weaker Bordeaux was applied without wettable sulfur (plot 7) the population was highest as was the ratio of scale fungi but with a somewhat lower percentage of living scales. In 1938, the infestation had increased in all plots but the rating remained the same, that is, the plots receiving the heavier residue copper sprays were more heavily infested.

Table 1.—The effect of copper sprays on the development of purple scale, (*Lepidosaphes beekii* (Newm.), Citrus Experiment Station, Lake Alfred, Fla.

Plot No.	Materials and Dilutions	1936*			1937†			1938†	
		Average Number Living Per Leaf	Per Cent Living	Average Number Fungi Per 100 Living Scales	Average Number Living Per Leaf	Per Cent Living	Average Number Fungi Per 100 Living Scales	Average Number Living Per Leaf	Average Number Fungi Per 100 Living Scales
1	Check	0.37	8	521	0.86	19	128	2.20	102
2	Check (1936) Basic copper 3-100, wettable Sulfur 10-100 (1937 and 1938)	0.37	11	521	0.80	20	52	4.88	24
3	Check	0.43	11	414	0.64	15	184	3.40	115
4	Bordeaux 3-3-100, wettable sulfur 10-100	1.08	15	281	2.40	29	75	3.88	78
5	Bordeaux 3-3-100, wettable sulfur 10-100 (1936) Bordeaux 6-6-100, wettable sulfur 10-100 (1937 and 1938)	1.49	15	212	3.00	24	33	10.28	39
6	Bordeaux 6-6-100, wettable sulfur 10-100	3.35	21	140	5.72	25	34	6.72	46
7	Bordeaux 3-3-100, spreader 1-100	4.26	20	136	8.00	23	80	14.88	68

* Before any treatment in 1936 there was an average of 0.09 living scale per leaf in all plots.
† No follow-up treatments were given except one fast sulfur spray to check rust mite infestation in July, 1937, and August, 1938.

INFLUENCE OF ZINC SPRAYS.—The importance of inert residues in the development of purple and red scales was further evident following the introduction of zinc sprays. Zinc compounds were first used as a spray on citrus in Florida by Camp (1934) to correct "frenching," a deficiency of zinc. It was soon observed that scales increased almost as rapidly following zinc sprays as they did following copper sprays. When it became evident that zinc would be applied more often as a spray than as a soil application it was included in the experimental spray schedule.

In 1936 an experiment was started and

continued through 1937 to determine the increase of purple scales when zinc sulfate was combined with Bordeaux mixture. Zinc sulfate–hydrated lime 5–2½–100 was applied alone and combined with Bordeaux 3–3–100, the experiment being conducted in a 15 year-old grapefruit grove. The copper and zinc sprays were applied in April during the period when copper sprays are applied for melanose control. Purple scale counts were made before any sprays were put on and again in November after all sprays for the season had been applied. Each plot consisted of two rows of five trees each. The results of the experiment are shown in table 2. Each year scales increased more rapidly following Bordeaux 3–3–100 plus zinc sulfate–lime 5–2½–100 (plot 5) than following Bordeaux 3–3–100 (plot 4). The Bordeaux-zinc combination contained 13½ pounds of inert residue per 100 gallons compared to 6 pounds in the straight Bordeaux. Each year in those two plots there was little or no difference in the ratio of scale fungi to living scales nor in the percentage of living. Where a straight zinc-lime spray (plot 2) was applied the scale population was not as high as in plot 3 which received Bordeaux alone, although there was slightly more residue in the zinc-lime sprays. The ratio of scale fungi to living scales was as high in that plot as in the check and about twice as high as in the Bordeaux plot. The scale population was slightly higher in the check plot than in the two plots just discussed, which is one of the few exceptions when there were more scales in the check than in the sprayed plots.

The value of wettable sulfur as a spray to check scales was again demonstrated in that experiment. The scale population was lower where the Bordeaux was supplemented with wettable sulfur (plot 4) than where it was omitted (plot 6). Where the follow-up of lime sulfur–wettable sulfur (plot 4) was applied, the scale population was also lower than where the lime sulfur spray was omitted (plot 3).

In 1936, another experiment was started and continued for 3 years to determine the degree of purple scale increase following various types of zinc sprays combined either with lime sulfur or wettable sulfur. The experiment was conducted in a 15-year-old pineapple orange grove that had a low uniform population of purple scales. Each plot consisted of 10 trees with buffer rows between plots. One hundred leaves were collected from the outside canopy of foliage of each tree and examined for scale by the method described. Examinations were made in the fall after all sprays had been applied for the season and again in the spring before any additional treatment. One plot received a zinc sulfate combined with lime sulfur; two others received zinc sulfate–lime, combined in one plot with lime sulfur

Table 2.—The control of purple scale, *Lepidosaphes beckii* (Newm.), following Bordeaux mixture and zinc sulfate sprays, Citrus Experiment Station, Lake Alfred, Fla.

Plot No.	Materials and Dilutions	Approximate Dates of Application	1936*†			1937†		
			Average Number Living Per Leaf	Per Cent Living	Average Number Attacked by Fungi Per 100 Living Scales	Average Number Living Per Leaf	Per Cent Living	Average Number Attacked by Fungi Per 100 Living Scales
1	Check		0.92	19	200	0.70	16	66
2	Zinc-lime 5–2½–100, wettable sulfur 5–100 Lime sulfur 1–60, wettable sulfur 5–100	April 26 May 19	0.26	16	200	0.56	21	51
3	Bordeaux 3–3–100, wettable sulfur 5–100	May 19	2.10	25	106	1.98	21	21
4	Bordeaux 3–3–100, wettable Sulfur 5–100 Lime sulfur 1–60, wettable sulfur 5–100	April 26 May 19	0.90	21	62	0.68	18	27
5	Bordeaux 3–3–100, zinc-lime 5–2½–100, wettable sulfur 5–100 Lime sulfur 1–60, wettable sulfur 5–100	April 26 May 19	1.70	21	163	5.02	35	23
6	Bordeaux 3–3–100, spreader 1–100 Lime sulfur 1–60, wettable sulfur 5–100	April 26 May 19	2.50	23	117	5.62	32	24

* Before treatment in 1936 there was an average of 3.0 living scales per leaf in all plots.
† Each year all plots received an oil spray, 1¼ per cent oil in 1936 and 1½ per cent oil in 1937.

and in the other with wettable sulfur; zinc oxide was combined with lime sulfur in one plot and with wettable sulfur* in another; a plot was sprayed with a basic zinc; and another with lime sulfur at the concentration used with the zinc compounds. The check plot was sprayed with only one fast lime sulfur spray each summer to check a heavy rust mite infestation. The number of applications per year, dilutions and detailed results are shown in table 3. In 1936, three applications of the above combinations were made with no follow-up sprays; but during the two following years only the spring application was made followed by two lime sulfur–wettable sulfur sprays in 1937, and in 1938, an oil spray was applied, in addition, to all plots that had received zinc. The oil was applied at a 1 per cent oil concentration instead of the recommended $1\frac{1}{4}$ or $1\frac{1}{2}$ per cent concentration so that the differences in scale build-up in the respective plots would still be distinct.

Table 3.—The effect of zinc sprays on the development of purple scale, *Lepidosaphes beckii* (Newm.), Citrus Experiment Station, Lake Alfred, Fla.*

Plot No.†	Materials and Dilutions	Average Number Living Scales Per Leaf and Number of Scale Fungi Per 100 Living Scales								
		October, 1936		February, 1937		November, 1937		February 1938	November, 1938	
		Number of Scales	Number of Fungi	Number of Scales	Number of Fungi	Number of Scales	Number of Fungi	Number of Scales	Number of Scales	Number of Fungi
1	Zinc sulfate 4–100, lime sulfur	1.01	18	4.00	23	4.56	117	3.28	0.64	22
2	Zinc oxide 2–100, lime sulfur	0.65	0	1.88	7	4.16	203	3.52	1.96	64
3	Zinc sulfate–Lime 4–2–100, lime sulfur	0.78	4	1.40	12	4.96	200	3.72	3.04	69
4	Basic zinc 8–100, lime sulfur	1.44	16	4.72	38	7.00	173	6.84		
5	Zinc sulfate–Lime 4–2–100, wettable sulfur	0.21	0	0.48	0	2.62	129	2.12	4.12	53
6	Zinc oxide 2–100, wettable sulfur	0.13	0	0.28	9	2.36	123	1.52	2.68	54
7	Lime sulfur	0.15	163	0.88	6	0.90	124	0.80	2.48	190
8	Check	0.75	190	0.74	142	0.84	41	0.92	2.04	118

* Before treatment in 1936 there was an average of 0.58 living scale per leaf in all plots.
† Program on plots 1–6, inclusive: 1936—3 applications zinc compounds with sulfur; 1937—1 application zinc compounds with sulfur plus 2 sulfur sprays; 1938—same as 1937 plus an oil spray.

By late October of 1936, the end of the first season, purple scales had increased in all plots where the zinc was combined with lime sulfur but had apparently decreased in the zinc–wettable sulfur plots. Where direct comparisons could be made there were slightly more scales in plots receiving zinc sulfate–lime than in those receiving zinc oxide. The most noticeable scale increase was obtained where basic zinc sulfate was applied at 8–100, this spray also carrying the largest amount of inert residue. The plot receiving zinc sulfate with lime sulfur (plot 1) had slightly more scales than the corresponding zinc-lime plot (plot 3), but unfortunately plot 1 was adjacent to a highway with heavy traffic. It is interesting to note the low ratio of scale fungi to living scales in all of the plots which received the three zinc sprays and the abundance of it in the lime sulfur and check plots.

Between October, 1936, and February, 1937, a period in which no sprays were applied, the scale population increased 100 to 300 per cent in all plots except the check. By November of 1937, there was a further increase in all of the zinc sprayed plots. However, the relative rating of infestation in the plots remained the same as it did the previous year except that plot 1 which received the zinc sulfate combined with lime sulfur had fewer scales than where zinc sulfate-lime plus lime sulfur was applied (plot 3). The ratio of scale fungi to living scales was much higher following one zinc spray per year than it had been in 1936 following three sprays. Between November, 1937, and February, 1938, the scale population decreased in all plots except the check. This

* The wettable sulfur used was 325 mesh containing 3 per cent blood albumin and 7 per cent conditioner.

would indicate that the high ratio of scale fungi to living scales in the zinc plots was responsible for the decrease, although it was not effective to the point of commercial control and the plots which received the heavier residues still had the heavier infestations of scales. By November, 1938, or the end of the third season, there was a more distinct difference between the plots receiving the heavy residue sprays than those receiving the lighter ones. Because of the heavy infestation of scale following the basic zinc 8–100 (plot 4) that material was not applied in 1938.

In 1938, the ratio of scale fungi to living scales was much lower in the zinc sprayed plots than it was the previous year. The low ratio was probably due to the oil spray applied in June before much of the zinc had been washed off by rains. Results of the first year's work indicate that zinc compounds, if present in appreciable amounts, are effective in preventing the development of the scale fungi, and the oil spray may be a means of causing the zinc residue to stick to the leaves longer, or there may be some other undetermined reason. The writer has observed that almost invariably when oil is mixed with copper sprays, and especially when it follows copper sprays, there is a much lower ratio of fungi to living scales than where coppers and sulfurs are combined or where the coppers are followed by sulfur sprays. Bearing on this point, 10 different experiments were examined covering a 5-year period and including 103 plots where direct comparisons could be made. Fifty-six plots received a copper spray combined with an oil or followed by an oil spray, and 47 plots received a copper spray combined with sulfur follow-up sprays. The ratio of scale fungi to living scales was lower in 53 of the 56 copper-oil plots than in the 47 copper-sulfur plots. The scale population was higher in 21 of the 47 copper-sulfur plots than in the corresponding plots where oil was used, but in most cases there was not enough difference in population to account for the high ratio of scale fungi to living scales in the copper-sulfur plots.

It has become a common practice to apply manganese sulfate as a spray to correct manganese deficiency. From general observations and the results of one year's work, indications are that purple scales will increase at about the same rate following manganese-lime sprays as following zinc sulfate–lime sprays. Purple scales increased more in a plot receiving a Bordeaux-zinc-manganese spray than where only Bordeaux-zinc sprays were applied (Thompson 1938).

Combinations of copper, zinc, manganese and lime leave a very heavy residue and when practical it is recommended that these materials be applied just before the growth starts in the spring so that the residue is applied only to the old growth. Without exception, scale increases have been less marked following dormant sprays leaving inert residues than when the sprays were applied both as dormant and post-bloom or as post-bloom alone (Thompson 1937a).

EFFECT OF COPPER SPRAYS ON OTHER CITRUS INSECTS AND MITES.—Other citrus insects besides purple and Florida red scales increase more rapidly following copper sprays than where these sprays have been omitted. Except for the comparison of populations of purple and Florida red scales, no comparisons have been made of other citrus insects following light and heavy residue sprays of fungicidal or of non-fungicidal properties.

Cloudy-winged whiteflies, *Dialeurodes citrifolii* (Morg.), apparently increased more rapidly following copper sprays than where no copper was applied. The writer has made no counts, but invariably there is more "sooty mold" on copper sprayed trees than on the unsprayed ones, which is an indication of a heavier whitefly infestation.

Citrus mealybug, *Pseudococcus citri* (Risso), infestations are also heavier on copper sprayed trees than in the checks. To illustrate: citrus mealybug population records made on June 30, 1938, on grapefruit trees that had been sprayed with a dormant Bordeaux in January, followed with a post-bloom Bordeaux in March, showed that there were no fruits free of mealybugs, 17 per cent lightly infested and 83 per cent medium to heavily infested; while in the unsprayed check 15 per cent were free, 68 per cent lightly infested and 17 per cent medium to heavily infested. Similar results have been observed in experimental plots during other years when mealybugs were abundant. Spear (1922) states that there was 5.5 per cent more mealybug injury on copper sprayed plots than on unsprayed trees

and that practically no mealybugs infected by fungus were found in the copper sprayed plots.

Rust mite, *Eriophyes oleivorus* (Ashm.), infestations also develop rapidly following copper sprays if wettable sulfur is not used as a supplement. Yothers & Mason (1930) reported that rust mites were more abundant following copper sprays than where these sprays were omitted. When the writer wishes to be assured of a heavy infestation of rust mites, a copper spray is applied with unusually consistent results, especially if mites are present in small numbers at the time the spray is applied.

It has been reported that purple mites or citrus red mites, *Paratetranychus citri* (McG.), also become more abundant following copper sprays than where no copper has been applied.

One of the more modern practices which has been adopted during the past 5 years and which has helped to offset some of the added difficulties in insect and mite control is the practice of combining wettable sulfur with the copper, zinc and manganese sprays. Rust mite control has been as effective commonly when wettable sulfur 5–100 was used as a supplement for Bordeaux mixture as when lime sulfur 2–100 was used (Thompson 1937b). Wettable sulfur has also been used to good advantage with the neutral coppers. As shown in tables 2 and 3, purple scale infestations were not as heavy where wettable sulfur 10–100 was combined with the coppers as where it was omitted. During 3 years of experimental work for the control of scab, scale and rust mites in the same schedule, the rust mites have been reduced to such a low level by supplementing the dormant and post-bloom copper sprays with wettable sulfur that no additional rust mite control was necessary in 2 years, and in 1 year a sulfur dust applied for mite control in late December was the only additional sulfur application necessary. The oil spray which followed the copper–wettable sulfur sprays also aided in checking rust mites. Plots where the wettable sulfur was omitted in the copper sprays required a sulfur spray for rust mite control

EFFECT OF FERTILIZER PRACTICES ON PURPLE SCALE DEVELOPMENT.—The recent changes in fertilizer practices have indirectly had an influence on purple scale development, especially in seedy grapefruit. Until it was discovered that "bronzing," the disappearance of the green color from the leaves, was due to a magnesium deficiency, purple scales were not as abundant or as difficult to control as they have been since that element has been added to the fertilizer formula. Formerly a very large percentage of the leaves would bronze if the tree had a crop of fruit, resulting in a very heavy leaf drop in the fall and winter. Purple scales do not develop on bronzed leaves to the extent that they do on green leaves, and this has been a factor in keeping purple scale infestations at a low level. Purple scales were more abundant on five plots of seedy grapefruit where there was a low percentage of bronzed leaves than on five adjacent plots where an extreme deficiency of magnesium existed with a high percentage of bronzed leaves. Citrus trees supplied with magnesium, zinc, manganese and copper as well as the ordinary fertilizer constituents withstand the crop strain better than formerly, and retain their leaves longer, which creates conditions favorable for purple scale development. The increased leaf area creates a denser shade, which is also favorable for purple scale development. Corroborating this statement is the fact that trees covered with half-shade in a slat house had more scales than adjancent trees without shade. Also, trees that were surrounded by a solid shade for windbreaks, but open at the top, had more scales than the adjacent trees, and, as shown by Thompson (1938), trees within the same plot had more scales on leaves where the foliage was fairly dense than on trees with sparse foliage.

CONCLUSION.—Heavy inert residue sprays of copper and zinc compounds not only inhibit the growth of entomogenous fungi which attack scale insects but create a condition favorable for purple and Florida red scale development, which appears to overshadow any appreciable effect the scale fungi might have. Purple scales were more abundant on trees with a high percentage of green leaves, where a magnesium deficiency had beeen corrected, than on trees with a high percentage of bronzed leaves, where the magnesium deficiency still existed.—3-13-39.

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Early Versus Late Poisoning and a Combination of Both for Boll Weevil Control

FLOYD F. BONDY, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine*

Since dusting with calcium arsenate for control of the boll weevil, *Anthonomus grandis* Boh. has two potentially important disadvantages, namely, injury to the sandy types of soils and the occurrence of aphids in large numbers after several successive applications, efforts have been made to prevent or partially prevent these evils by reducing the quantity of the chemical used. This practice was begun several years ago with presquare poisoning and dusting with calcium arsenate and varying amounts of diluents. Previous experiments had indicated that, under conditions of light weevil damage, satisfactory and economical control could be obtained in South Carolina (Bondy 1938) by using diluted calcium arsenate. In 1938 there was an opportunity to test diluted calcium arsenate and presquare treatments under conditions of moderately heavy weevil damage.

ARRANGEMENT OF PLOTS.—The studies were conducted near Florence, S. C., and consisted of 20 field-plot experiments. In two of the experiments there were two plots each, in 15 experiments three plots each and in three experiments four plots each, a total of 61 plots. In the two-plot experiments one plot was treated and one was left as an untreated check, in the three-plot experiments two were treated and one was left as a check, and in the four-plot experiments two were treated and two were checks. In the two-plot and three-plot experiments the plots were parallel and adjacent, whereas in the four-plot experiments they were arranged in a quadrangle with the two treated plots placed diagonally.

Each plot was approximately three-fourths of an acre in size and consisted of 30 rows, 250 to 300 feet long, selected because of the apparent uniformity of soil, stand and growth of cotton. All the treatments were in duplicate except two, which were in triplicate.

TREATMENTS.—Calcium arsenate was the only insecticide used. Applications were made by various methods and at different times, but the experiments may be divided into the following general groups: (1) Control, directed against weevils coming out of hibernation, by presquare treatments, early treatments or a combination of the two; (2) control by the presquare treatments followed by dust treatments after 10 per cent of the squares had become infested; (3) control by dusting after 10 per cent of the squares had become infested.

In group 1 the presquare treatments were given to the terminal buds of the young cotton plants before the squares were large enough for the weevils to puncture them. They consisted of a mixture of 1 pound of calcium arsenate, 1 gallon of water and 1 gallon of molasses, or of 1 pound of calcium arsenate and 1 gallon of water without the molasses, applied with a burlap mop; undiluted calcium arsenate dust, applied with a rotary hand duster, shaker can, burlap bag or a horse muzzle lined with 16-mesh screen wire; and calcium arsenate and hydrated lime in equal proportions, ap-

Table 1.—Summary of data obtained in poisoning experiments for the control of the boll weevil, Florence, S. C., 1938.

Treatment*	Average Number of Applications	Average Amount of Poison Per Acre Per Application	Average Seasonal Infestation, Per Cent		Average Yield of Seed Cotton Per Acre, Pounds		Average Number of Pounds of Seed Cotton Gained or Lost	Average Profit or Loss Per Acre, Dollars	Average Cost Per 100 Pounds Gain, Dollars
			Check	Treated	Check	Treated			
Group 1, presquare and early treatments:									
Calcium arsenate, water and molasses (presquare, burlap mop)	3	2.65 gal.	11.08	8.53	855	877	22	−0.42	5.91
Calcium arsenate and water (presquare, burlap mop)	3	2.45 gal.	12.85	6.40	954	1,020	66	1.44	1.80
Calcium arsenate and hydrated lime (presquare, rotary hand duster)	3	4.54 lb.	11.08	8.34	855	930	75	1.74	1.68
Calcium arsenate, undiluted (presquare, rotary hand duster)	3	5.62 lb.	8.18	6.20	625	632	7	−1.68	28.00
Calcium arsenate, undiluted (presquare, shaker-can duster)	3	4.51 lb.	8.18	7.75	625	630	5	−1.40	32.00
Calcium arsenate, undiluted (presquare, horse-muzzle duster)	3	13.79 lb.	6.99	5.62	1,128	1,121	−7	−3.72	—
Calcium arsenate, undiluted (presquare, burlap-bag duster)	3	10.59 lb.	6.99	6.95	1,128	1,070	−58	−5.11	—
Calcium arsenate and hydrated lime (presquare and early, rotary hand duster)	6†	4.59 lb.	12.85	4.66	954	1,030	76	0.66	1.82
Calcium arsenate, water and molasses (presquare, burlap mop)	3	2.60 gal.							
Calcium arsenate and hydrated lime (early, rotary hand duster)	3	4.70 lb.	13.07	7.35	873	996	123	2.58	1.90
Calcium arsenate and hydrated lime (early, rotary hand duster)	3	4.70 lb.	13.07	6.37	873	907	34	0.22	3.35
Group 2, presquare and late treatments:									
Calcium arsenate, water and molasses (presquare, burlap mop)	3	2.68 gal.							
Calcium arsenate, undiluted (late, rotary hand duster)	5	6.26 lbs.	21.68	9.61	1,116	1,566	450	13.54	0.99
Calcium arsenate, water and molasses (presquare, burlap mop)	3	2.72 gal.							
Calcium arsenate and hydrated lime (late, rotary hand duster)	5.5	6.34 lb.	27.81	13.05	831	1,315	484	15.54	0.79
Calcium arsenate, water and molasses (presquare, burlap mop)	3	2.56 gal.							
Calcium arsenate and sulfur (late, rotary hand duster)	5	9.74 lb.	22.65	12.26	619	973	354	10.03	1.16
Calcium arsenate, water and molasses (presquare, burlap mop)	3	2.55 gal.							
Calcium arsenate and calcium carbonate (late, rotary hand duster)	4.5	9.77 lb.	16.53	9.31	904	1,289	385	11.62	0.98
Group 3, late treatments:									
Calcium arsenate, undiluted (rotary hand duster)	6.3	6.93 lb.	23.77	8.63	677	1,199	522	16.91	0.76
Calcium arsenate and hydrated lime (rotary hand duster)	5.5	6.07 lb.	20.95	8.89	711	1,063	352	11.73	0.67
Calcium arsenate and sulfur (rotary hand duster)	6.5	10.31 lb.	27.74	10.21	645	1,129	484	15.48	0.80
Calcium arsenate and calcium carbonate (rotary hand duster)	6.3	10.17 lb.	29.78	15.74	594	1,018	424	12.99	0.94

* The early treatments were applied following presquare treatment and before 10 per cent of the squares became infested, and the late treatments after 10 per cent of the squares had become infested.
† Three applications presquare and three applications early.

plied with a rotary hand duster. Shaker cans made from ordinary cardboard mailing tubes 12 to 14 inches long by 2 to 3 inches in diameter, with metal bottoms perforated with 6 to 10 small openings, proved satisfactory for dusting the terminal buds of small cotton plants. The screen-lined muzzles were designed to sift the dust by a rotary motion, but these and the burlap bags for shaking the poison were not very satisfactory. Three presquare applications of poison by these methods were made at 5-day intervals beginning just as the first squares appeared on the plants. The early treatments were applied after the squares had become large enough for oviposition, or during the period following presquare treatment and before 10 per cent of the squares became infested. Three applications of the dusts were made with rotary hand dusters at 5-day intervals. The combination treatment consisted of three presquare and three early treatments and were designed to keep the poison on the cotton throughout the period when most of the weevils were emerging from hibernation.

In group 2, three presquare moppings with the molasses–water–calcium arsenate mixture were used. These treatments were followed, after 10 per cent of the squares had become infested, by dusting with undiluted calcium arsenate or calcium arsenate mixed with lime, sulfur or calcium carbonate in equal proportions.

In group 3 the late treatments consisted of dusting with calcium arsenate or the mixtures of calcium arsenate and lime, sulfur or calcium carbonate after 10 per cent of the squares had become infested.

METHODS OF OBTAINING DATA.—During the presquare stage of the cotton, weevil population counts were made weekly by recording the number of weevils found on 200 plants near each end and in the middle of each plot. After the squares had become large enough for oviposition these counts were discontinued and square-infestation records were made by examining 200 squares at each end and in the middle of each plot. These infestation counts were made at weekly intervals until the end of the fruiting period. At weekly intervals throughout the blooming period counts were made of the white blooms of the six middle rows in each plot. At the end of the fruiting period counts were made of all the bolls present on 25 linear feet at each end and in the middle of each of the four middle rows in each plot. Yield records were obtained from representative areas (in no case less than one-third of the total area) in each plot. The net profit per acre and the cost of the treatment per 100 pounds of gain were computed by allowing 4 cents per pound for seed cotton and deducting the following charges: 7 cents per pound for calcium arsenate, 15 cents per gallon for molasses, 1 cent each per pound for lime, sulfur and calcium carbonate, 12 cents per hour for applying the mop mixtures, and 24 cents per hour for applying the dust mixtures.

RESULTS.—The data from these experiments are summarized in table 1.

DISCUSSION.—None of the presquare treatments when used alone, gave any appreciable gains over the untreated checks. In most cases these treatments gave no profits and the cost per 100 pounds of gain was high. The presquare treatments plus the early treatments resulted in only slightly higher increases in gain, with an almost negligible profit and a high cost per 100 pounds of gain. Neither of the above methods is considered satisfactory for boll weevil control. The presquare mopping treatments followed by dusting treatments after 10 per cent square infestation gave high increases in pounds of seed cotton, comparatively high profits and reasonably low costs per 100 pounds of gain. In general, the dust treatments after 10 per cent infestation resulted in the greatest gains, the highest profits and the lowest cost per 100 pounds of gain.

Of the four dusts tested, undiluted calcium arsenate applied after 10 per cent of the squares were infested gave larger average yields of seed cotton and greater average profit per acre than any of the other treatments. On light sandy soils, however, where there is danger of soil injury from the use of too much calcium arsenate, the treatment that ranked second in average profit per acre is recommended as the most practical method of control. This treatment consisted of three moppings of a mixture of 1 pound of calcium arsenate, 1 gallon of molasses and 1 gallon of water applied at the average rate of 2.72 gallons per acre during the presquare stage, followed by dusting,

after 10 per cent of the squares were infested, with a mixture of equal parts of calcium arsenate and lime. An average of 5.5 dust applications was made. An average of only 21.51 pounds of calcium arsenate per acre was used in this treatment as compared to an average of 43.70 pounds of calcium arsenate per acre in the treatment that gave the highest yields and profits per acre.

The use of presquare treatments delays the date when 10 per cent of the squares become infested and reduces the number of later dust applications. This in turn reduces the danger of soil injury and of building up damaging aphid infestations.

Where presquare applications of poison have not been made and there is danger of soil injury, dusting with a mixture of equal parts of calcium arsenate and lime is recommended, as in the experiments reported here this method gave the most economical gain, although the total increase in yield and the profit per acre were not so high as with some of the other treatments. Dusting with a mixture of equal parts of calcium arsenate and sulfur also gave good increases in yield and profit per acre, and this treatment is advisable if the flea hopper, tarnished plant bug or red spider is abundant.

SUMMARY.—In field experiments against the boll weevil at Florence, S. C., in 1938, calcium arsenate and several mixtures containing calcium arsenate were applied to cotton in presquare and early treatments, presquare and late treatments, and late treatments alone. The results of these experiments showed that none of the presquare or early treatments when used alone gave satisfactory control. The most economical gain, based on cost of production, was obtained by the use of a dust mixture of calcium arsenate and hydrated lime after 10 per cent square infestation. Owing to the necessity of using as little calcium arsenate as possible to avoid soil injury and heavy aphid infestations, the use of a mixture of molasses, water and calcium arsenate in the presquare stage, followed by dusting with a mixture of calcium arsenate and hydrated lime after 10 per cent square infestation, is considered the most practical method of boll weevil control on light sandy soils. —3-27-39.

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Progress Report on Mixtures of Calcium Arsenate and Sulfur for Control of the Boll Weevil at State College, Miss.

R. L. MCGARR,* *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine*†

Field-plot tests were conducted at State College, Miss., in 1938 to compare the efficacy of mixtures of calcium arsenate and sulfur (1:2 and 1:1) with calcium arsenate alone in controlling the boll weevil, *Anthonomus grandis* Boh. These two mixtures had been used at Port Lavaca, Tex., in 1936 and 1937 in the presence of heavy boll weevil infestations and light infestations of the cotton flea hopper, *Psallus seriatus* (Reut.), and, under these conditions, had brought about higher yields of cotton than calcium arsenate alone. The tests at Port Lavaca were made in the heavy-blackland section of Texas, whereas those at State College were made in the hill section or on the lighter soil types of Mississippi.

The calcium arsenate and sulfur used in the tests were commercial products and the mixtures were factory prepared. Two types of plot tests were made and for convenience they will be referred to as small-plot and large-plot tests.

SMALL-PLOT TESTS.—Each small plot was 12 rows wide and of sufficient length to contain one-tenth of an acre. These plots were arranged in randomized blocks, comparisons being made in each block between the 1:2 and 1:1 calcium arsenate–sulfur mixtures, calcium arsenate alone and a check. The tests were located

* Thanks are due F. F. Bibby for assistance in making the field-plot records used in this paper.

† In cooperation with the Mississippi Agricultural Experiment Station and the Mississippi State Plant Board.

in four fields of cotton. Fields 1 and 2 each contained 4 blocks, or 16 plots, and fields 3 and 4 each contained 2 blocks, or 8 plots; thus there was a total of 48 plots, or 12 tests with each of the three insecticides and their check. The tests were located in cotton planted early in the season. Applications that were washed off by rain in less than 24 hours were not considered effective.

Four effective poison applications were made in each field. The dusting was begun after approximately 10 per cent of the squares had become infested, and, as nearly as possible, the applications were repeated at 5-day intervals when the infestation exceeded 10 per cent in the treatment showing the best control. The applications were made with one-row rotary hand dust guns. An average per acre-application of 13.7 pounds of the 1:1 and 1:2 mixtures and 7.1 pounds of calcium arsenate was made.

Five infestation records were made in fields 1 and 2 and four records in fields 3 and 4. Two hundred squares were examined per plot for each boll weevil infestation record. The first records were made on June 27 and 30 and the last on July 26 and 28. In each field the first infestation record was made the day prior to the first poison application. The average infestations after dusting was started in the 12 plots of each treatment were as follows: 1:2 mixture, 26.9 per cent; 1:1 mixture, 24.8 per cent; calcium arsenate, 25.5 per cent; and check, 40.3 per cent. Records of cotton flea hopper population were usually made in connection with the records of boll weevil infestation, but at no time were flea hoppers found in sufficient numbers to be considered injurious.

The average gain in production of seed cotton and the net profit per acre for each treatment were as follows: 1:2 mixture, 300 pounds of cotton and a net profit of $7.05; 1:1 mixture, 294 pounds and a net profit of $6.46; and calcium arsenate, 266 pounds and a net profit of $6.16. The average production for the check plots was 1,082 pounds per acre.

Analysis of variance‡ of the yields in the randomized plots showed that the effect of each poison treatment differed significantly from that of the untreated check but that there was no significant difference between poison treatments. The required difference for significance was 116 pounds of seed cotton per acre. However, the average gains and profits were slightly better from the mixtures than from the calcium arsenate.

LARGE-PLOT TESTS.—Two series of tests were made in large (two-thirds-acre) plots. In series 1 the 1:2 mixture of calcium arsenate and sulfur, calcium arsenate alone and a check were compared. This test was replicated three times (cuts *A*, *B* and *E*). There were three replications (cuts *C*, *D* and *F*) of series 2, in which the 1:1 mixture of calcium arsenate and sulfur, calcium arsenate alone and a check were compared. The tests of series 1 were located in cotton planted early in the season, whereas those of series 2 were located in cotton planted about the middle of the season. The insecticides were applied in the same manner as in the small-plot tests.

Three poison applications in series 1 were made in each of cuts *A* and *E* and four in cut *B*. One application was washed off by rain in each of cuts *B* and *E*. The 1:2 mixture was applied at the rate of 13.8 pounds per acre-application in the three cuts of series 1, and the calcium arsenate was applied at the rate of 6.8 pounds.

In series 2, seven poison applications were made in each of cuts *C* and *F*, and eight in cut *D*. One application was washed off in each of cuts *C* and *D* and two in cut *F*. The average quantities of the 1:1 mixture and calcium arsenate applied per acre-application in the three cuts were 13:1 and 7 pounds, respectively. Two applications of nicotine-lime dust for cotton aphid control were made in each of the treated plots in cut *C* and in the calcium arsenate–treated plot in cut *D;* one application of the nicotine-lime dust was made in the plot treated with 1:1 mixture in cut *D* and in each of the treated plots in cut *F*.

Three hundred squares were examined per plot for each record of boll weevil infestation in the large plots. Flea hopper inspections were made as in the small plots, but no injurious flea hopper infestation was recorded. In each test the first infestation record was made 1 or 2 days prior to the first poison application.

Five infestation records were made in cut *A*, four in cut *B* and three in cut *E*

‡ Thanks are due R. C. Gaines for the analysis of variance of yields herein recorded.

of series 1. The first records were made in cuts *A*, *B* and *E* on July 1, 7 and 13, respectively. The last records were made on July 25 and 27. The average infestation in the three cuts, after dusting had been started, was 14.8 per cent in the plot treated with the 1:2 mixture, 13.5 per cent in the plot treated with calcium arsenate and 34.5 per cent in the check plot.

In series 2, five infestation records were made in each of cuts *C* and *D* and three in cut *F*. The first records in cuts *C* and *D* were made on July 9 and in cut *F* on July 21; the last records were made on August 9. The average infestation in the three cuts, after dusting was started, was 13.7 per cent in the plot treated with the 1:1 mixture, 14.4 per cent in the plot treated with calcium arsenate and 45.4 per cent in the check plot.

The average gain in production and net profit per acre for each treatment in series 1 were as follows: For the 1:2 mixture, 91 pounds gain in yield and a net profit of $0.57; and for the calcium arsenate, 145 pounds gain and a net profit of $2.85. The average production for the check plots was 1,096 pounds per acre. The small gains in production in this series from each treatment can be attributed to the fact that weevil infestation in the check plots was not sufficiently high to prevent a normal crop from being set.

The average gain in production and the net profit per acre for each treatment in series 2 were as follows: For the 1:1 mixture, 666 pounds gain and a net profit of $17.84; and for the calcium arsenate, 626 pounds gain and a net profit of $17.37. The average production for the check plots was 1,144 pounds per acre. The large increases in production in this series were due to the excellent boll weevil control (average infestation of 14 per cent in the treated plots) given by the treatments under conditions favorable for severe boll weevil damage, and the subsequent loss of cotton in the untreated plots (average infestation of 45.4 per cent in the untreated plots).

In both the small and large plots the cotton plants were usually more vigorous where the mixtures containing sulfur were used than where calcium arsenate alone was applied, and there were fewer cotton aphids.

SUMMARY.—Tests were made on small (one-tenth-acre) plots dusted with a 1:2 mixture of calcium arsenate and sulfur, a 1:1 mixture of calcium arsenate and sulfur, and calcium arsenate alone, each replicated 12 times for control of the boll weevil. The infestation records showed very little difference in the control obtained with the different insecticides. While the yield records showed no significant difference between the insecticides, the average gains and profits were slightly in favor of the mixtures over the calcium arsenate. Tests on large (two-third-acre) plots on which a comparison was made of results from a 1:2 mixture of calcium arsenate and sulfur and from calcium arsenate alone, on early planted cotton with a light weevil infestation, gave practically no gains from either treatment. Similar large plots dusted with a 1:1 mixture of calcium arsenate and sulfur and with calcium arsenate alone, on late planted cotton with heavy weevil damage in untreated plots, gave large gains and profits in both cases, with slightly better results from the mixture than from the calcium arsenate.—3-27-39.

Boll Weevil Control Tests With Calcium Arsenates Containing Different Percentages of Water-Soluble Arsenic Pentoxide

R. C. GAINES, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine*

Cage tests reported by Smith, Scales & Gaines (1938) and laboratory tests by Gaines (1938) indicated that there was considerable difference in the toxicity and effectiveness of calcium arsenates containing different percentages of water-soluble arsenic pentoxide as determined by the New York method (Pearce *et al.* 1935). Therefore, it was considered desirable to test such calcium arsenates in the field at as many localities as possible, with different soils, climatic and growth

conditions, and varying degrees of weevil infestation. Tests* were made against the boll weevil at Florence, S. C., Gainesville, Fla., State College, Miss., Tallulah, La., Port Lavaca, Tex., and College Station, Tex., by the U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine, and at the last locality by the Texas Agricultural Experiment Station, also. Two tests were made by the Bureau at College Station, making a total of eight tests. A variety of cotton commonly grown in the locality was used in seven of the tests and sea-island cotton was used at Gainesville.

PLOT ARRANGEMENTS AND TREATMENTS.—The plots were arranged in randomized blocks and each treatment was replicated from four to seven times in each locality. There was a total of 45 replications. Each plot was eight rows wide and of sufficient length to give it an area of one-thirtieth of an acre. An untreated buffer area 7 feet wide surrounded each plot. The treatments consisted of calcium arsenate containing on an average 0.5, 4.6 and 10.3 per cent of water-soluble arsenic pentoxide as determined by the New York method.† These calcium arsenates have been designated as low, intermediate and high, respectively. The low and intermediate calcium arsenates contained an average of 43.5 per cent of total arsenic pentoxide, and the highs 45.5 per cent. The calcium arsenates were applied with hand guns at the rate of 5.4 to 6.9 pounds per acre at five-day intervals. The treatments were begun when about 10 per cent of the squares were found to be punctured.

RECORDS.—Infestation records (percentage of squares punctured) were made at approximately 5-day intervals on the day preceding a poison application. A total of 200 squares were examined in each plot and all punctured squares, both egg and feeding punctures, recorded. Counts were made on the four middle rows in each plot. The infestation records made during the dusting period were averaged for each plot. Records made prior to that period were not included in the averages. Cotton was picked from the four middle rows of each plot, the picking area being one-sixtieth of an acre.

Table 1.—Mortality records of boll weevils and cotton leaf worms with various calcium arsenates, Tallulah, La., 1938.

CALCIUM ARSENATE	WATER-SOLUBLE ARSENIC PENTOXIDE, PER CENT	NET MORTALITY IN CAGES, PER CENT		MEDIAN LETHAL DOSE FOR FIFTH-INSTAR LEAF WORMS, MILLIGRAMS PER GRAM OF BODY WEIGHT
		Boll Weevil	Leaf Worm	
Low	0.4	73	91	0.17±0.05
Intermediate	4.5	95	98	0.13±0.04
High	10.5	91	99	0.12±0.02
Significant difference		7	3	

RESULTS.—Table 1 gives mortality records of boll weevils and cotton leaf worms from cage and laboratory tests at Tallulah, La. The net mortalities caused by intermediate and high calcium arsenates did not differ significantly, but both intermediate and high differed significantly from the low. On the basis of body weight, there was little difference in the quantity of calcium arsenate of low, intermediate and high water-soluble arsenic pentoxide content required to kill 50 per cent of the population of fifth-instar leaf worms (median lethal dose).

Table 2 summarizes boll weevil infestations at the different localities and yields of seed cotton from plots treated with calcium arsenates of low, intermediate and high percentages of water-soluble arsenic pentoxide. The average increase in yield for low calcium arsenate was 3.8 pounds per plot, or 20.3 per cent, for intermediate 3.0 pounds, or 16.0 per cent,

* Records at Florence, S. C., were made by F. F. Bondy, C. F. Rainwater, R. L. Walker and J. H. Gayden; at Gainesville, Fla., by C. S. Rude, G. H. Rainwater and E. H. Solomon; at State College, Miss., by R. L. McGarr and F. F. Bibby; at Tallulah, La., by R. C. Gaines, M. T. Young, G. L. Garrison, R. W. Goins, K. H. Smith and G. A. Thompson, Jr.; at Port Lavaca, Tex., by K. P. Ewing, D. H. Alexander, C. R. Parencia, Jr., C. Legett, Jr., and F. R. Jackson; at College Station, Tex., No. 1 by J. C. Gaines, D. F. Martin and R. B. Eads, and Nos. 2 and 3 by R. W. Moreland, A. B. Beavers, A. Kagan and R. C. Vittetoe. The work at College Station was done in cooperation with the Texas Agricultural Experiment Station. Cage tests at Tallulah, La., were made by G. L. Smith, A. L. Scales, G. C. Woodruff and J. A. Fontenot. Dosage-mortality records at Tallulah, La., were made by G. A. Thompson, Jr., C. A. Richmond and R. C. Gaines.

† All chemical analyses were furnished by the Division of Insecticide Investigations.

Table 2.—Boll weevil infestations and yields of seed cotton at various localities after treatments with different calcium arsenates, 1938.

Locality	Number of Replications	Percentage of Squares Punctured				Pounds of Seed Cotton Per Plot			
		Plots Treated with Calcium Arsenate*			Check Plots	Plots Treated with Calcium Arsenate*			Check Plots
		Low	Intermediate	High		Low	Intermediate	High	
Florence, S. C.	6	18.2	14.2	13.5	30.4	21.1	19.6	22.3	14.5
Gainesville, Fla.	7	19.3	18.8	18.2	32.8	16.4	13.1	12.9	10.6
State College, Miss.	6	15.2	17.1	16.8	25.2	22.3	22.1	22.3	21.9
Tallulah, La.	6	21.2	18.6	17.5	45.1	37.2	36.6	35.6	32.3
Port Lavaca, Tex.	6	6.9	7.3	6.6	14.6	19.3	20.3	20.0	18.8
College Station, Tex., No. 1	5	11.2	9.1	11.5	18.1	15.4	15.3	14.5	14.0
College Station, Tex., No. 2	5	6.4	7.2	7.4	16.6	20.1	19.3	18.6	17.3
College Station, Tex., No. 3	4	12.8	10.5	9.5	36.9	30.6	30.6	30.8	21.0
Weighted average	—	14.3	13.3	13.0	27.6	22.5	21.7	21.8	18.7
Percentage increase per plot over check	—	—	—	—	—	20.3	16.0	16.6	—

* Low, intermediate and high indicate the water-soluble arsenic pentoxide content of the calcium arsenate.

Table 3.—Analyses of variance of infestations and of yields at the different localities, 1938.

Locality and Source of Variation	Checks Included			Checks Not Included		
	Degrees of Freedom	Mean Square		Degrees of Freedom	Mean Square	
		Infestations	Yields		Infestations	Yields
Florence, S. C.						
Between treatments	3	368.7**	69.4	2	38.2	10.9
Between blocks	5	33.9	26.2	5	34.1	36.8
Error	15	19.9	22.7	10	15.0	24.9
Gainesville, Fla.						
Between treatments	3	347.7**	39.9**	2	2.2	26.4**
Between blocks	6	203.6	14.7	6	150.6	7.9
Error	18	4.5	3.5	12	2.3	2.6
State College, Miss.						
Between treatments	3	121.8**	0.2	2	5.7	0.1
Between blocks	5	33.4	1.9	5	25.3	1.7
Error	15	18.9	5.8	10	15.8	6.7
Tallulah, La.,						
Between treatments	3	1,026.2**	28.7*	2	21.6	3.9
Between blocks	5	33.3	30.1	5	8.2	39.1
Error	15	42.1	6.6	10	22.9	3.5
Port Lavaca, Tex.						
Between treatments	3	89.0**	2.5	2	0.9	1.4
Between blocks	5	4.5	7.3	5	2.6	7.8
Error	15	1.4	7.9	10	0.6	8.4
College Station, Tex., No. 1						
Between treatments	3	77.1	2.4	2	8.6	1.2
Between blocks	4	28.3	1.9	4	4.4	9.8
Error	12	62.1	17.9	8	30.4	15.8
College Station, Tex., No. 2						
Between treatments	3	114.9**	7.3**	2	1.5	3.1**
Between blocks	4	33.0	0.6	4	7.8	0.2
Error	12	8.2	0.2	8	2.3	0.1
College Station, Tex., No. 3						
Between treatments	3	684.1**	92.8**	2	11.5*	0.1
Between blocks	3	19.2	2.7	3	10.9	2.6
Error	9	4.7	6.9	6	1.6	9.8

* Significant.
** Highly significant.

and for high 3.1 pounds, or 16.6 per cent.

ANALYSES OF RESULTS.—Table 3 gives the analyses of variance (Snedecor 1938) of infestations and of yields at the different localities. For each locality the mean squares are given of both infestations and yields for between treatments, for between blocks, and for treatment-block discrepance or error. Analyses were made both with the checks included and with the checks omitted. When the checks were included in the analyses it will be noted that the difference between the treatment infestations was highly significant at seven of the eight localities and nonsignificant at only one locality. When the checks were not included this difference was significant at only one locality and nonsignificant at the other seven. The infestation records were in observed percentages, which were transformed to equivalent angles (Bliss 1938) for use in the analysis of variance. The conclusions from the analyses using the equivalent angles were identical to those using percentages. When the checks were included the difference between the treatment yields was highly significant at three localities, significant at one and nonsignificant at the other four. When the checks were not included this difference was highly significant at two localities and nonsignificant at the other six.

Table 4 gives the analyses of variance (Snedecor 1938) of infestations and of yields at all localities. When the checks were included in the analyses, the differences between treatment infestations and between treatment yields were highly significant. When the checks were not included these differences were not significant. The conclusions regarding treatment infestations from the analyses using equivalent angles were identical to those using percentages. In other words, there was no significant difference between calcium arsenates containing low, intermediate and high percentages of water-soluble arsenic pentoxide by the New York method. The only significant differences were between poison treatments and the untreated checks.—3-27-39.

Table 4.—Analyses of variance of infestations and of yields at all localities, 1938.

Source of Variation	Checks Included					Checks Not Included				
	Degrees of Freedom	Infestations		Yields		Degrees of Freedom	Infestations		Yields	
		Sum of Squares	Mean Square	Sum of Squares	Mean Square		Sum of Squares	Mean Square	Sum of Squares	Mean Square
Between treatments	3	6,737	2,246*	400	133*	2	40	20	18	9
Between localities	7	5,872	839	8,514	1,216	7	2,963	423	6,888	984
Treatment-locality discrepance	21	1,751	83	330	16	14	140	10	75	5
Between blocks	37	2,050	55	433	12	37	1,336	36	522	14
Treatment-block discrepance (error)	111	2,202	20	987	9	74	842	11	651	9
Total	179	18,612	—	10,664	—	134	5,321	—	8,154	—

* Highly significant.

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Additional Records on the Effectiveness of Several Insecticides Against Three Cotton Insects

G. L. Smith, A. L. Scales and R. C. Gaines, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine**

The efficacy of several insecticides and mixtures of insecticides was tested in 1938 at Tallulah, La., against three cotton insects, namely, the boll weevil, *Anthonomus grandis* Boh., the cotton leaf worm, *Alabama argillacea* (Hbn.), and the tarnished plant bug, *Lygus pratensis* (L.). The cage tests were a continuation of tests made during the two previous seasons, the methods and results of which have been discussed by Smith & Scales (1937) and by Smith, Scales & Gaines (1938). In the cage tests reported herein the net mortality in each cage was computed by using the formula $(X-Y)100/X$ with X as the percentage of live insects in the check cage and Y the percentage in the treated cage. The net mortalities were then used in the analysis of variance to determine the required difference for significance between the means of treatments. The laboratory tests reported herein with fifth instar cotton leaf worms were a continuation of the tests made during the previous season, the methods and results of which were reported by Gaines (1938).

Tests with 14 Brands of Commercial Calcium Arsenate.—The results of the tests made in 1937 have already been discussed by Smith, Scales & Gaines (1938) but are repeated here so that comparisons of results for the two seasons can be made. In 1937 the coefficient of correlation between the percentage of water-soluble As_2O_5 by the New York method (Pearce, Norton & Chapman 1935) and net mortality of boll weevils was +0.72 (P=between 0.05 and 0.02). The coefficient of correlation between these same two variables in 1938 was +0.81 (P= less than 0.01). The coefficient of correlation in 1937 was significant and in 1938 highly significant. There also appears to be considerable relation between water-soluble As_2O_5 and net mortality of the cotton leaf worm, the samples having the highest water-soluble As_2O_5 usually causing the highest mortalities and those containing low water-soluble As_2O_5 causing somewhat lower mortalities. The results for the tests of 1938 are based on 18 replications. The average mortality of boll weevils in check cages was 22 per cent and in the cotton leaf worm check cages it was 10 per cent.

The doses, table 1, required to kill 50, 95 and 99 per cent of fifth instar cotton leaf worm populations were determined by the methods discussed by Gaines (1938) and were computed from the data according to the method of Bliss (1938). The dose-mortality curves were plotted with the ordinates as probits of percentage mortality and the abscissas as logarithms of milligrams per gram of body weight. The dose-mortality curves were computed and the doses required to kill 50, 95 and 99 per cent of the populations were also computed. The doses required to kill 50 per cent of the population, with their probable average limits of error for odds of 19 in 20, are given in table 1 for five calcium arsenates. The probable average limits of error for the doses required to kill 95 and 99 per cent of the populations were exceedingly large but the doses serve the purpose of showing the differences in toxicity between calcium arsenates having a low percentage of water-soluble As_2O_5 by the New York method, an intermediate percentage of water-soluble As_2O_5 and a high percentage of water-soluble As_2O_5. In general it will be noted that the smallest doses were required for the calcium arsenates (I. D. 3689 and 3890) containing high percentages of water-soluble As_2O_5 and that the largest doses were required for the calcium arsenate (I. D. 3851) containing a low percentage, with the intermediates (I. D. 3935 and 3681) falling between the low and high.

Tests With Calcium Arsenate and Sized Fractions Thereof.—Table 2 presents net mortalities of boll weevils and of cotton leaf worms caused by three commercial calcium arsenates and four fractions of each calcium arsenate. The

* The authors were assisted in the field by G. C. Woodruff and J. A. Fontenot and in the laboratory by G. A. Thompson, Jr., and C. A. Richmond. All chemical analyses reported in this paper were furnished by the Division of Insecticide Investigations, Bureau of Entomology and Plant Quarantine.

Table 1.—Results of tests against the boll weevil and the cotton leaf worm with 14 brands of commercial calcium arsenate.

CALCIUM ARSENATE I. D. NO.	TOTAL As_2O_5, PER CENT	WATER-SOLUBLE As_2O_5, PER CENT		NET MORTALITY, PER CENT				DOSE* IN MILLIGRAMS REQUIRED TO KILL FIFTH INSTAR COTTON LEAF WORMS		
				Boll Weevil		Cotton Leaf Worm				
		A.O.A.C. Method	N. Y. Method	1937	1938	1937	1938	M.L.D.†50 Per Cent	95 Per Cent	99 Per Cent
3935T26	43.1	—	4.5	—	95	—	98	0.13±0.04	0.56	1.05
3689	42.5	0.16	8.3‡	72	94	96	—	0.10±0.02	0.32	0.51
3890	46.8	—	10.5	—	91	—	99	0.12±0.02	0.25	0.34
3698	44.7	0.20	8.4	52	89	94	—	—	—	—
3681	40.3	0.09	4.4‡	72	86	93	—	0.20±0.02	0.45	0.63
3847	41.7	—	9.8	—	85	—	—	—	—	—
3683	42.6	2.75	4.1	67	84	95	—	—	—	—
3679	45.8	0.14	0.5‡	47	77	90	—	—	—	—
3680	44.5	0.11	0.8	49	76	85	—	—	—	—
3715	41.6	0.3	0.9	42	75	81	—	—	—	—
3714	40.9	0.2	0.5	39	75	85	—	—	—	—
3937	42.1	—	3.0	—	74	—	—	—	—	—
3851	43.7	—	0.4	—	73	—	91	0.17±0.05	1.57	3.95
3713	46.2	0.0	0.3	48	73	83	—	—	—	—
For significance, two treatments must differ by				12	7	11	3	—	—	—

* Milligrams per gram of body weight.
† Median lethal dose.
‡ These percentages, which were determined in 1938, differ slightly from the percentages reported for the same samples in 1937.

fractions were prepared by the Division of Insecticide Investigations, Bureau of Entomology and Plant Quarantine, by means of a centrifugal air separator, and therefore differed in particle-size distribution. There was considerable chemical separation of samples I. D. 3689 and 3681 but the chemical separation of 3679 was not so marked. Here again the relation between the percentage of water-soluble As_2O_5 by the New York method and the net mortality of boll weevils is apparent, the coefficient of correlation being +0.72 (P = less than 0.01).There are also some differences of cotton leaf worm mortalities in favor of the samples containing

Table 2.—Tests against the boll weevil and the cotton leaf worm with three original commercial calcium arsenates and four fractions of each original calcium arsenate.

TREATMENT	AVERAGE SIZE OF PARTICLES, DIAMETER IN MICRONS*	WATER-SOLUBLE As_2O_5 N. Y. METHOD, PER CENT	NET MORTALITY, PER CENT		DOSE† IN MILLIGRAMS REQUIRED TO KILL FIFTH INSTAR COTTON LEAF WORMS		
			Boll Weevil	Cotton Leaf Worm	M.L.D.‡ 50 Per Cent	95 Per Cent	99 Per Cent
Calcium arsenate I. D.3 689. Fraction 3	8.0	9.9	93	98	—	—	—
4	14.0	12.5	91	100	0.18±0.02	0.38	0.52
Original	13.0	8.3	90	100	0.10±0.02	0.32	0.51
Fraction 2	5.0	7.0	81	98	—	—	—
1	2.5	2.3	51	91	0.06±0.02	0.40	0.90
Calcium arsenate I. D. 3681. Fraction 4	9.0	6.9	87	99	—	—	—
Original	8.0	4.4	84	99	0.20±0.02	0.45	0.63
Fraction 3	6.0	5.1	80	97	—	—	—
1	4.4	2.6	75	95	0.13±0.04	0.52	0.91
2	4.2	2.8	70	94	—	—	—
Calcium arsenate I. D. 3679. Fraction 4	7.0	0.44	83	95	—	—	—
3	5.0	0.40	78	91	—	—	—
Original	6.0	0.49	70	88	—	—	—
Fraction 2	4.4	0.50	61	89	—	—	—
1	3.7	0.63	54	88	—	—	—
For significance, two treatments must differ by	—	—	8	3	—	—	—

* Physical properties of the samples furnished by the Division of Insecticide Investigations, Bureau of Entomology and Plant Quarantine.
† Milligrams per gram of body weight.
‡ Median lethal dose.

Table 3.—Tests against the boll weevil with a commercial calcium arsenate, di-calcium arsenate, two basic calcium arsenates, nicotine bentonite, nicotine bentonite and tannate and mixtures of commercial calcium arsenate and sulfur.

Treatment*	Total As_2O_5, Per Cent	Water-Soluble As_2O_5, Per Cent, N. Y. Method	Net Mortality, Per Cent
Sample C, di-calcium arsenate	60.7	—†	91
Sample B, basic calcium arsenate	52.8	1.8	71
Calcium arsenate, T 26, I. D. 3935	43.1	4.5	70
Sample A, basic calcium arsenate	53.7	5.3	64
Calcium arsenate–sulfur (factory mixed) 1:1	—	—	63
Calcium arsenate–sulfur (factory mixed) 1:2	—	—	59
Nicotine bentonite and tannate (3.75 per cent nicotine)	—	—	21
Nicotine bentonite (3.00 per cent nicotine)	—	—	17
For significance, two treatments must differ by	—	—	12

* Samples A, B and C, together with information on their chemical properties, were furnished by the Division of Insecticide Investigations, Bureau of Entomology and Plant Quarantine. Sample A, a basic calcium arsenate containing no free lime and having a molecular ratio CaO/As_2O_5 of 3.23; sample B, a basic calcium arsenate containing no free lime and having a molecular ratio CaO/As_2O_5 of 3.42; sample C, a practically pure di-calcium arsenate with the formula $CaHAsO_4 \cdot H_2O$.
† Much more soluble than the two basic samples B and A.

the highest percentages of water-soluble As_2O_5. The coefficient of correlation between the average size of particles and net mortality of boll weevils was +0.78 (P = less than 0.01). The coarsest samples were most effective and the finest samples were least effective. These results are based on 24 replications for the boll weevil and on 18 for the cotton leaf worm. The average mortality in the boll weevil check cages was 31 per cent and it was 8 per cent in the cotton leaf worm check cages. The doses required to kill 50, 95 and 99 per cent of fifth instar cotton leaf worms are also given in this table for five samples. The doses required to kill 50 per cent of the populations do not check with the net mortalities in cages, but the doses required to kill 99 per cent of the populations check fairly well with cage net mortalities.

TESTS WITH DI-CALCIUM ARSENATE, BASIC CALCIUM ARSENATES, COMMERCIAL CALCIUM ARSENATE, CALCIUM ARSENATE AND SULFUR MIXTURES, AND NICOTINE BENTONITE.—Di-calcium arsenate, table 3, caused the highest boll weevil mortality, and this differed significantly from the mortalities caused by the two basic calcium arsenates and the commercial calcium arsenate. The calcium arsenate–sulfur mixtures caused a somewhat lower mortality than the calcium arsenate but the differences were not significant. Nicotine bentonite and nicotine bentonite and tannate caused significantly lower mortali-

Table 4.—Tests against the boll weevil and the cotton leaf worm with one commercial calcium arsenate and mixtures of calcium arsenate with three wetting agents.

Treatment	Net Mortality, Per Cent	
	Boll Weevil	Cotton Leaf Worm
Calcium arsenate,* T 10, I. D. 3927 alone	77	100
Calcium arsenate with 1 per cent wetting agent A†	79	99
Calcium arsenate with 1 per cent wetting agent B‡	79	100
Calcium arsenate with 1 per cent wetting agent C§	78	96
Calcium arsenate with 0.6 per cent wetting agent A	84	97
Calcium arsenate with 0.6 per cent wetting agent B	80	100
Calcium arsenate with 0.6 per cent wetting agent C	80	99
Calcium arsenate with 0.3 per cent wetting agent A	82	98
Calcium arsenate with 0.3 per cent wetting agent B	83	99
Calcium arsenate with 0.3 per cent wetting agent C	79	99
For significance, two treatments must differ by	—	3

* Contained 4.2 per cent water-soluble As_2O_5 by the N .Y. method and 43.0 per cent total As_2O_5.
† Wetting agent A, a commercial product containing sulfonated alkylated diphenyl (Aresket 300).
‡ Wetting agent B, a commerca product containing a sodium salt of an alkylated naphthalenesulfonate (Vatsol—Os).
§ Wetting agent C, a commercial product containing monosodium sulfonate of butylphenyl phenol (Areskap 100).

ties than any of the other insecticides or mixtures tested in this series. These net mortalities are based on 18 replications, and the mortality in the check cages averaged 23 per cent.

TESTS WITH CALCIUM ARSENATE AND MIXTURES OF CALCIUM ARSENATE AND WETTING AGENTS.—In the tests against the boll weevil, table 4, the *F* value was found to be nonsignificant, which indicates that the boll weevil net mortalities did not vary more than would be expected had the samples been drawn from a homogeneous population. There were very few significant differences between the means of net cotton leaf worm mortalities. The addition of from 0.3 to 1.0 per cent of wetting agents to commercial calcium arsenate does not appear to increase or decrease significantly the net mortality of boll weevils and of cotton leaf worms. The results in these tests against the boll weevil are based on 21 replications and the average mortality in the check cages was 25 per cent. For the cotton leaf worm, net mortalities are based on 18 replications and the average mortality in check cages was 10 per cent.

TESTS WITH DERRIS, DERRIS-SULFUR MIXTURE, AND SULFUR.—Table 5 presents net mortalities of adults of *Lygus pratensis* caused by derris, by derris-sulfur mixture and by sulfur, and by mixtures of these with three wetting agents. The addition of wetting agents to these insecticides and mixtures does not appear materially to affect the net mortality. These results are based on nine replications. The average mortality in the check cages on cotton was 27 per cent and on the weed host plant, *Erigeron canadensis*, it was 47 per cent.

TESTS WITH CALCIUM ARSENATE AND CRYOLITES.—Table 6 gives net mortalities of boll weevils and of cotton leaf worms caused by one commercial calcium arsenate, three cryolites, and mixtures of cryolites and wetting agents. The three cryolites caused significantly lower mortalities of boll weevils than calcium arsenate, and the cotton leaf worm mortalities were also somewhat lower with the cryolites. The addition of wetting agents to the cryolites does not appear to change materially the effectiveness of the original samples. These results are based on 15 replications in the boll weevil tests and 9 replications in the cotton leaf worm tests. The average boll weevil mortality in the untreated check cages was 19 per cent and for the cotton leaf worm 8 per cent.

Table 5.—Tests against *Lygus pratensis* adults with derris, derris-sulfur mixture, sulfur and mixtures of derris, of derris-sulfur mixture, and of sulfur with three wetting agents.

TREATMENT	NET MORTALITY, PER CENT	
	Cotton	*Erigeron canadensis*
Derris, 4.3% rotenone, alone	35	49
Derris, with 1 per cent wetting agent B	39	42
Derris, with 1 per cent wetting agent C	35	40
Derris, with 1 per cent wetting agent A	36	30
Derris-sulfur mixture 1:3 alone	20	46
Derris-sulfur with 1 per cent wetting agent B	34	43
Derris-sulfur with 1 per cent wetting agent C	41	28
Derris-sulfur with 1 per cent wetting agent A	28	36
Sulfur alone	20	13
Sulfur with 1 per cent wetting agent B	19	14
Sulfur with 1 per cent wetting agent C	14	20
Sulfur with 1 per cent wetting agent A	13	13

SUMMARY.—Definite positive correlations are shown between net boll weevil mortality and the percentage of water-soluble As_2O_5 by the New York method. Dose-mortality records with fifth instar cotton leaf worms showed that smaller doses were required of calcium arsenates containing a high percentage of water-soluble As_2O_5 and larger doses were required of calcium arsenates containing a low percentage of water-soluble As_2O_5, the intermediate percentages falling between the low and high. Definite relations are also shown between the percentage of water-soluble As_2O_5 by the New York

Table 6.—Tests against the boll weevil and the cotton leaf worm with one commercial calcium arsenate, three cryolites and mixtures of three cryolites with three wetting agents.

Treatment	Fluorine Found, Per Cent	Equivalent to Cryolite Na_3AlF_6 Per Cent	Net Mortality, Per Cent	
			Boll Weevil	Cotton Leaf Worm
Calcium arsenate T 26, I. D. 3935 alone*			84	100
Cryolite I. D. 4038 alone	49.3	90.8	34	81
Cryolite with 1 per cent wetting agent C			42	62
Cryolite with 1 per cent wetting agent A			48	54
Cryolite with 1 per cent wetting agent B			35	73
Cryolite I. D. 3668 alone	38.0	69.9	35	82
Cryolite with 1 per cent wetting agent C			28	72
Cryolite with 1 per cent wetting agent A			27	66
Cryolite with 1 per cent wetting agent B			29	68
Cryolite I. D. 4037 alone	42.5	78.3	47	98
Cryolite with 1 per cent wetting agent C			33	99
Cryolite with 1 per cent wetting agent A			45	98
Cryolite with 1 per cent wetting agent B			39	96
For significance, two treatments must differ by			13	10

* See table 1 for analysis of this sample.

method and net boll weevil mortality with calcium arsenate fractions prepared by means of a centrifugal air separator. Dicalcium arsenate was more effective against the boll weevil than either basic calcium arsenate or a commercial calcium arsenate. The addition of wetting agents to calcium arsenate, to derris, to derris-sulfur mixture, to sulfur and to cryolites did not appear to affect significantly the insect mortality resulting from use of these insecticides.—2-27-39.

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Control of the Boll Weevil on Sea-Island Cotton

Paul M. Gilmer, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine*

Between 1915 and 1925 sea-island cotton production in the continental United States dropped from over 75,000 bales a year to practically nothing. While certain other factors played their part in this spectacular blotting out of a flourishing industry, the major cause of its demise was the activity of the boll weevil, *Anthonomus grandis* Boh., which reached the sea-island belt about 1916. Because of the very long fruiting season of sea island cotton, and also because the bolls are susceptible to weevil attack until practically mature, growers were unable to produce this cotton in the presence of the weevil with the methods of control then in use. The sea-island cotton was rapidly replaced by Egyptian, Peruvian and other long-stapled varieties, until in 1925 less than 10 bales were produced in the old sea-island belt.

When the growers in Florida in 1935 attempted to revive the industry, it was necessary to turn to the U. S. Department

of Agriculture for planting seed that had been preserved and line-bred in the South Caroline coastal area to conserve a pure-line strain. Fortunately, during the first 2 years of the comeback, ecological conditions throughout the sea-island belt were highly unfavorable to the weevil, and good crops were produced even without weevil control, so that more farmers were encouraged to return to the production of sea-island cotton.

By 1937 sea-island cotton production had expanded in both northern Florida and southern Georgia until five to ten thousand acres were in production in the two states. Growers who attempted to control the weevils generally used a modification of the sweetened-poison mop employed in earlier years and still used over the area for controlling weevils on upland cotton. The weather was dry during 1935 and 1936 and the first seasonal broods of weevils caused little damage; therefore this method of control was given much more credit than the facts warranted.

In 1937 the cycle of dry Junes, the crucial month for first brood larvae, was broken. Although in that season an exceedingly small hibernating brood of weevils emerged, so small in fact that practically no damage was caused to upland cotton, favorable weather for weevil development during June and July produced a heavy migrating brood late in July and early in August. Fields of sea-island cotton that had shown excellent crops, and that apparently had excellent weevil control previous to this midsummer migration, suffered severe damage from migratory weevils, so that in many cases the prospects for a good crop were wiped out. Sweetened poison applied in southern Georgia by the method used in Florida failed to control the weevils, and growers had to resort to dusting with calcium arsenate, usually when it was too late to help. On the whole, 1937 was a disastrous year to sea-island cotton producers, since a wet August and September resulted in a poor grade of lint, which added to the loss from heavy weevil damage.

During 1937, experiments in weevil control were conducted in cooperation with the Georgia Coastal Plain Experiment Station on a series of plots at Tifton, Ga., and on a farm near Lake Park, in Echols County, which was utilized as a pure-seed block. A cooperative project with the office of the Georgia State Entomologist located near Savannah was also undertaken. The results for that season were given at the previous meetings of the Cotton States Branch (Gilmer 1938). The present paper deals primarily with the continuation of the field-plot work at Tifton during 1938, although the conclusions drawn are based on the results obtained during both years.

EXPERIMENTAL PROCEDURE.—The results of the 1937 season had shown clearly that under southern Georgia conditions mopping with sweetened poison was inadequate for sea-island cotton, but that in light initial infestations heavy dustings or spray schedules would permit the production of profitable crops in spite of rather heavy weevil infestations later in the season. The experiments of 1937 had also shown that most presquare applications were of little or no benefit. It was decided then to concentrate on the spray and dust programs in 1938, making presquare poisoning and the testing of diluted arsenicals a minor portion of the plot set-up. Accordingly, a series of one-half-acre plots, in which the following three major treatments were randomized, were laid out in a block: (1) The sprayed series, in which a mixture of calcium arsenate, sirup and water (5 pounds to 1 gallon to 49 gallons) was applied by a traction-operated tobacco sprayer at the rate of 15 to 25 gallons per acre throughout the season; (2) the standard dust series, in which calcium arsenate dust was applied by means of a rotary hand gun at the rate of 4 to 7 pounds per acre per application whenever infestation reached 10 per cent or more in any plot; and (3) the intensive dust series, in which calcium arsenate was applied in the same way and at the same rate as in the standard dust series, but whenever infestation reached 5 per cent in any plot.

Conditions beyond the control of the experimenter made it necessary to use the results from only a portion of the plots laid out. Seedling plants in the earlier planted portion of the field were severely injured by frost on April 2, before the plants on the rest of the field had broken through the ground. Some of the plots on the northern edge were discarded because of gross variations in stand and plant growth between treatments. Two of the three plots in the sprayed and standard dust series and one plot in the intensive dust series lay in the central section of the

field, where stand, vigor, soil fertility and other conditions were fairly uniform. Only one check plot was utilized. This plot was among the earliest to break ground and yet escape the freeze of April 2. It was located upon soil of more than average fertility, somewhat distant from sources of early infestation, and it was one of the last plots to develop an infestation. The stand here was better than that on any other plot, although the number of plants per acre was not sufficiently greater to be seriously out of line with the other plots. Yields of seed cotton from the check plot were 60 to 75 pounds higher than yields from unpoisoned cotton produced commercially in the vicinity.

insecticides but also the labor for picking and ginning the gains. These costs were estimated at the following rates: Calcium arsenate at 7 cents a pound, sirup at 45 cents a gallon, labor and machine depreciation at 15 cents per acre-application for dusting and 20 cents for spraying, picking seed cotton at $1.75 per 100 pounds, and ginning at $9 per 400-pound bale.

DISCUSSION OF RESULTS.—A very noticeable effect on weevil control on sea-island cotton is the improvement in grade and increase in value of the lint. Sea-island cotton differs from upland cotton in that the bolls do not open so wide, the cotton is retained within the boll to a

Table 1.—Grades, average yield, value of lint and seed, cost of treatment and increase in crop value per acre due to boll weevil control on sea-island cotton, Tifton, Ga., 1938.

TREATMENT	YIELD, POUNDS		GRADE NO.	VALUE OF LINT PER POUND, CENTS	TOTAL VALUE OF LINT AND SEED,* DOLLARS	COST OF TREATMENT, DOLLARS	INCREASE IN CROP VALUE FROM TREATMENT, DOLLARS
	Seed Cotton	Lint					
Intensive dust	530	154	1	25	41.88	10.33	10.62
Standard dust	503	146	1	25	39.71	9.21	9.57
Spray	454	131	2	22	31.72	6.63	4.16
Check	350	104	4	18	20.93	—	—

* All seed was valued at the oil-mill price of 90 cents per 100 pounds.

The standard-dusted cotton received 9 effective dustings, counting the redusting of two washed-off applications (removed within 24 hours) as a single application, and the intensive-dusted 10 effective applications, each averaging 6.5 pounds of calcium arsenate per acre per application. The sprayed cotton received only 7 applications, averaging 20 gallons per acre, since further applications of the sirup would have caused damage to opening cotton. It is probable that the final dust applications, made on August 15 and 22, were of little or no value. They were made to protect the large number of small bolls in the tops of the dusted plants, but improper fertilization, combined with unseasonable hot and dry weather at that time, caused complete defoliation of the plants and total loss of this portion of the crop.

RESULTS.—The effectiveness of these treatments was judged by comparing the average yield, value of lint and seed, and increase in crop value with the cost of treatment. These data are given in table 1. The cost of treatment includes not only the materials and labor for applying the

much greater extent, and weevilly locks, unless almost completely destroyed, are very little different in external appearance and accessibility from normal locks.

As a result of these differences, and since pickers' wages are usually based on weight of seed cotton, a much larger percentage of weevilly locks is likely to be picked in sea-island than in upland cotton. The presence of a few weevilly locks in a pound of seed cotton is sufficient to cause it to run seriously off grade, owing to discoloration. The differences in grade and price of dusted, sprayed and unpoisoned cotton given in table 1 are due primarily to this factor, slightly influenced by the added fact that the picker is not inclined to pick the poorer grade of untreated cotton so free of trash as he will the cotton in the treated plots, which is evidently of better quality. Since the final test of the efficacy of a control program is in terms of income and profit per acre rather than in pounds of seed and lint alone, this factor should not be overlooked in evaluating a program involving a high-priced product such as sea-island cotton with a wide range in the prices of grades.

The effect of this factor of grade is confirmed by the case of the cotton produced on a field under observation in 1938 on the Broadfield plantation near Valdosta, Ga. This plantation produced 34 bales of cotton, averaging 370 pounds of lint. The cotton was treated for weevils and picked with special care. Ginned as picked it would have been classed as no. 1 grade, valued at approximately 25 cents per pound for the 12,600 pounds of lint. The owner, however, in an endeavor to produce superquality cotton had this seed cotton carefully hand-sorted and all trash and weevilly locks removed. The selected cotton ginned 32 bales and the trash cotton, ginned separately, gave 2 bales. The hand-selected cotton was graded as Fancy no. 1, for which 30 cents a pound was offered, while the two bales of trashy cotton graded a poor no. 3 or a fair no. 4, worth approximately 15 cents per pound. The total lint income from the 12,600 pounds of lint without hand picking would have amounted to $3,150. The same cotton hand picked was valued at $3,658. The cost of hand picking was 1.5 cents per pound of lint, or $189, leaving a profit of $319, due solely to betterment of grade. This profit, it is to be noted, was on cotton grading no. 1. The difference between poisoned and weevilly unpoisoned cotton in 1938 was a full two grades or better, or the difference between a price of 25 cents a pound for no. 1 and 15 to 20 cents a pound for poor no. 3 or fair no. 4. In practice this increase in crop value would represent a fair profit above all production costs on the dusted cotton, about an even break on the sprayed cotton, and a loss on the season's operations on the unpoisoned cotton, although the yield differences in pounds of seed cotton amounted to only about 40 or 50 pounds of lint per acre.

The crop year of 1938 was characterized by the heaviest weevil infestation known in southern Georgia for a number of years. Owing to peculiar meteorological conditions, this was not apparent in field records before the appearance of the second seasonal or midsummer migrating brood. A dry and rather cool May held cotton back until late in the month. Beginning with a rainy period about May 20, cotton took on a growth that might be characterized as "explosive," producing squares in such large numbers almost immediately after setting the first squares as to mask totally the effects of the heavy spring infestation. This flush squaring continued throughout most of June and until late in July, resulting in a remarkably heavy bottom crop, which saved many operators from a total loss when the midsummer migration came. About July 20 migration commenced and before August 1 oviposition had begun. In unpoisoned fields all top forms were blasted, a large portion of the middle crop already set was ruined, and some inroads were made upon the bottom crop than commencing to open. Earliness or lateness of planting made all the difference between complete loss and an approach to an even break for fields that were unpoisoned. The early-planted fields usually produced 250 to 300 pounds of seed cotton per acre, of no. 3 or no. 4 grade, whereas many of the late-planted fields were not worth picking.

SUMMARY.—Sea-island cotton was heavily infested and severely damaged by the boll weevil in 1938. In experiments conducted at Tifton, Ga., the following insecticidal treatments were tested against the weevil: Calcium arsenate applied at the rate of 6.5 pounds per acre per application when 5 per cent of the squares were infested (intensive dust series); calcium arsenate applied at the same rate when 10 per cent of the squares were infested (standard dust series); and calcium arsenate, sirup and water (5 pounds to 1 gallon to 49 gallons) applied at the rate of 15 to 25 gallons per acre throughout the season (sprayed series). All treated plots gave increases in yield over the untreated check plot, the treatments being effective in the order listed.

The dusted plots produced lint of no. 1 grade, valued at 25 cents a pound, the sprayed plots no. 2 grade, valued at 22 cents a pound, and the check plot no. 4 grade, valued at 18 cents a pound.

The gains in yield and the improvement in grade from weevil control resulted in an increased crop value, over cost of treatments, of about $10 per acre in the dusted plots and about $4 in the sprayed plots.—3-3-39.

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Factors Influencing the Formation of the Venom of the Honeybee

W. M. Lauter and V. L. Vrla,* *Rochester, N. Y.*

In connection with an investigation carried out to determine chemically as well as physiologically the venom produced by the honeybee, *Apis mellifera* L., it was observed that not only did the quantities of venom change with the age of the insect but that food changes definitely influenced the formation of the venom.

We are greatly indebted for the help obtained from K. A. Forster and E. Muller,‡ who first drew our attention to these facts and who have suggested to us the methods used in this investigation.

The earlier opinion that bee venom consisted mainly of formic acid was first shown to be wrong by Langer (1897) who found that bee venom consists of a complicated substance which he believed to be an organic base. Flury (1920) advanced the opinion that bee venom is related to the snake venoms and might be similar to cantharidine. Later investigators generally agreed that the main action of bee venom was caused by a nitrogenous substance, apparently a proteosis. The presence of histamine has also been proved.

The preparation of larger amounts of bee venom, and the standardization of such batches on the basis of the neurotoxic action on the albino mouse, made it necessary to determine whether the yields might be improved by changes in the diet of the insects. The chemical investigations published during the past few years made it probable that the bee, to form venom, would require a diet composed partly of proteins. It was therefore suggested to determine whether bees on a pollen-free sugar diet would produce as much venom as bees which had access to pollen. E. Muller in a private communication had already informed us that he had found that the intestines of the honeybee from the third to the tenth day of life in all cases were full of pollen. Beginning with the eleventh day of life, this presence of pollen decreases steadily until at the twenty-sixth day only microscopically small amounts of pollen could be seen. We were able to check these observations in general.

Venom and Diet.—Two hundred young bees just emerged were kept in a celluloid cage which did not allow the entrance of other bees. They were fed on a sugar solution. At the tenth day the sting apparatus was removed from 160 of these inclosed insects. Eighty venom sacs were cut open and washed with water. The remaining 80 venom sacs were fixed with absolute alcohol. The venom was precipitated by alcohol. After it was dried in a desiccator over calcium chloride, the following results were obtained:

80 dried venom glands emptied of venom weighed 1.15 milligrams
1 dried venom gland emptied of venom weighed 0.014 milligram
80 dried filled venom glands weighed 2.6 milligrams
1 dried filled venom gland weighed 0.0325 milligram

Therefore a bee kept on a sugar diet from the first until the tenth day of its life produces on the average 18.5 gamma dried venom.

In order that the results with young bees which had ample access to pollen (protein) diet might be compared, 300 young bees, just emerged, were marked with small tinfoil pieces. At the tenth day, 160 were caught and divided into two batches of 80 each. The washing and fixation of the venom sacs was done as described in the above experiment. The following results were obtained:

80 dried venom glands emptied of venom weighed 1.2 milligrams
1 dried venom gland emptied of venom weighed 0.015 milligram
80 dried filled venom glands weighed 7.4 milligrams
1 dried filled venom gland weighed 0.093 milligram

Therefore, a bee 10 days old which has had a normal pollen diet produces on the average 79 gamma dried venom.

This dried venom roughly compares to about 0.237 milligram liquid natural venom. The average maximum total liquid venom quantity found by Langer is 0.3–0.4 milligram. It seems, therefore, that not only does a lack of pollen diet result in a formation of less venom, but we find that the insect has formed a

* Both authors, Research Department of the R. J. Strasenburgh Co., Rochester, N.Y.

† Personal communication from K. A. Forster and E. Muller, Research Laboratories of the H. Mack Co., Ulm.

majority of the venom at its tenth day of life.

In other words, for the production of venom it is not advisable to use bees which are fed on an artificial exclusive sugar diet. We are now conducting experiments in which we are feeding bees on diets of sugar solutions in which vegetable lecithin and albumin are suspended in order to determine if an artificial diet of this type may be found to increase venom production to higher than normal levels. The results we hope to be able to publish later.

VENOM AND AGE.—These results induced us to determine when the formation of the venom begins and whether it declines in later life. Five hundred young bees were marked on the first day of their life. One hundred sixty were taken on the fifth day and divided into two batches. The isolation and fixation of the venom sacs in water as well as in alcohol were carried out as described above. The following results were obtained:

80 dried venom glands emptied of venom weighed 1.0 milligrams
1 dried venom gland emptied of venom weighed 0.013 milligram
80 dried filled venom glands weighed 5.1 milligrams
1 dried filled venom gland weighed 0.064 milligram

Therefore, a bee during the first 5 days of its life produces on the average 51 gamma dried venom, or roughly 50 per cent of the total amount, if we consider 0.35 milligram liquid natural total venom as the maximum average amount that it produces.

One hundred sixty bees were taken on their twenty-fifth day of life and divided as above into two batches of 80 bees each. The following results were obtained:

80 dried venom glands emptied weighted 1.1 milligram
1 dried venom gland emptied weighed 0.014 milligram
80 dried filled venom glands weighed 9.9 milligrams
1 dried filled venom gland weighed 0.124 milligram

Therefore, a bee 25 days of age produces on the average 110 gamma of dried venom. This is equivalent to about 0.33 milligram, which is practically the normal total maximum liquid amount of venom ever found in a bee.

Table 1.—Summary of venom study with the honeybee.

Age of Bee in Days	Gamma Dried Venom	Equivalent in Original Liquid Venom	Diet	
			Natural (Pollen)	Artificial (Sugar)
5	51	0.153 milligram	+	
10	79	0.237 milligram	+	
10	18.5	0.056 milligram		+
25	110	0.330 milligram	+	

SUMMARY.—This work was carried out in June and July and was done on bees of the Italian race. It is summarized below and in table 1.

It appears, although, of course, the possibility of errors due to the preparation difficulties of the venom sacs is considerable, that the honeybee, Apis millifera L., produces about half of its venom within the first 5 days of its life and that it keeps its venom intact at least up to the twenty-fifth day.

A sugar diet devoid of pollen is undesirable for the production of bee venom. A possibility might exist of artificially supplying proteins to be used in the synthesis of bee venom by the insect.—4-27-39.

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THE Federal Seed Act, approved August 9, 1939, repealing the Act of 1912, prohibits the transportation or sale in interstate commerce of agricultural or vegetable seeds, unless labeled as to identification, origin in certain cases and percentage of weeds or inert matter. It further provides that certain imported seeds must meet specified quality requirements and that alfalfa and red clover seed be stained to show adaptability as influenced by origin, and prohibits false labeling.

Common Insects Attacking Sugar Beets and Vegetable Crops in the Salt River Valley of Arizona

K. B. McKinney, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine*

In the geographically isolated Salt River Valley of Arizona, which was formerly classified as a desert but has been brought to a high state of cultivation through irrigation, the production of truck and garden crops on a commercial scale has led to an interesting development in the occurrence, adaptation and increase in abundance on these crops of many species of common insects.

Although comparatively small acreages of vegetables were grown by the early settlers in this region, and cantaloupes and sweet potatoes were first produced in the Valley during 1904 in such volume as to permit carload shipments, it was not until the completion of the Roosevelt Dam in 1911 permitted a marked expansion of the area under cultivation that the truck and garden crop industry attained an important agricultural status. By the close of 1937, however, the area devoted to truck and garden crops, exclusive of home gardens, had increased to approximately 40,000 acres. This comprises approximately 10 per cent of the total of 420,000 acres of irrigated land in the Valley.

During the period extending from 1932 to 1937, inclusive, the author has found the following species of insects and closely related forms occurring commonly on sugar beets and vegetable crops in the Salt River Valley of Arizona:

The More Common Insects Attacking Sugar Beets and Vegetable Crops in the Salt River Valley of Arizona and the Principal Crops They Attack*

Orthoptera

Melanoplus differentialis (Thos.), differential grasshopper.
Sugar beet† cabbage, cauliflower, lettuce.
Melanoplus mexicanus (Sauss.).
Sugar beet, cabbage, cauliflower, lettuce.
Melanoplus yarrowi (Thos.).
Sugar beet, lettuce.
Trimerotropis pallidipennis (Burm.).
Sugar beet, cabbage, cauliflower, lettuce.
Conozoa sulcifrons (Scudd.).
Sugar beet, cabbage, cauliflower, lettuce.
Conozoa carinata Rehn.
Sugar beet, cabbage, cauliflower, lettuce.
Encoptolophus pallidus subgracilis Caud.
Sugar beet, cabbage, cauliflower, lettuce.
Derotmema haydenii laticinctum Scudd.
Sugar beet, cabbage, lettuce.
Gryllus assimilis (F.), field cricket.
Cabbage, lettuce.

Thysanoptera

Frankliniella tritici (Fitch), flower thrips.
Bean, garden pea, squash, tomato.
Thrips tabaci Lind, onion thrips.
Bean, *garden beet*, sugar beet, *cabbage*, cantaloupe, cauliflower, cucumber, onion.
Scoloythrips sexmaculatus Perg.
Bean.
Kurtomathrips morrilli Moult.
Bean.
Hercothrips sp.
Bean.
Hercothrips fasciapennis (Hinds).
Irish potato.
Aeolothrips sp.
Irish potato.

Hemiptera

Pycnoderes quadrimaculatus Guer., squash mirid
Bean, cantaloupe, cucumber, *lettuce*, squash, watermelon.
Nysius ericae (Schill.), false chinch bug.
Garden beet, *sugar beet*, radish.
Lygus hesperus Kngt.
Sugar beet.
Lygus pratensis oblineatus (Say).
Sugar beet.
Chlorochroa sayi Stål, Say's stinkbug.
Sugar beet.
Euschistus impictiventris Stål.
Sugar beet.
Thyanata custator (F.).
Sugar beet.
Anasa tristis (DeG.), (variety), squash bug.
Cucumber, squash, watermelon, cantaloupe.
Corizus hyalinus (F.).
Lettuce.

Homoptera

Stictocephala festina (Say), three-cornered alfalfa hopper.
Bean, *lettuce, turnip.*
Myzus persicae (Sulz.), green peach aphid.
Bean, garden beet, sugar beet, Irish potato, radish, *tomato.*
Brevicoryne brassicae (L.), cabbage aphid.
Cabbage, cauliflower.
Rhopalosiphum pseudobrassicae (Davis), turnip aphid.
Cabbage, cauliflower, turnip.
Aphis gossypii Glov., melon aphid.
Cantaloupe, cucumber, squash, watermelon.
Macrosiphum (Illinoia) pisi (Klth.), pea aphid.
Garden pea.

* Crops shown in roman type are injured commonly to an important degree by the designated insect. The crops shown in italics are injured ordinarily only to a minor degree; or the status of the designated insects as pests of these crops has not been determined definitely.

† All references to sugar beet as a host plant refer principally to this crop as grown for seed.

Table 1.—Number of species of insects occurring commonly on sugar beets and vegetable crops in the Salt River Valley of Arizona.*

	Crop Plant																		
Order	Bean	Beet (Garden)	Beet (Sugar)	Cabbage	Cantaloupe	Cauliflower	Cucumber	Lettuce	Okra	Onion	Pea (Garden)	Pepper	Potato (Irish)	Sweet Potato	Radish	Squash	Tomato	Turnip	Watermelon
Orthoptera	—	—	8	8	—	6	—	9	—	—	—	—	—	—	—	—	—	—	—
Thysanoptera	5	1	1	1	1	1	1	—	—	1	1	—	2	—	—	1	1	—	—
Hemiptera	1	1	6	—	1	—	2	2	—	—	—	—	—	—	1	2	—	—	2
Homoptera	2	2	2	2	1	2	1	1	—	—	1	—	5	—	2	1	3	2	1
Coleoptera	3	—	4	1	4	2	4	6	1	—	—	—	1	—	—	3	1	3	6
Lepidoptera	1	—	8	9	1	5	1	13	—	—	2	2	3	1	1	1	11	1	1
Diptera	1	—	—	—	2	—	1	—	—	—	—	—	—	—	—	1	—	—	1
Totals	13	4	29	21	10	16	10	31	1	1	4	2	11	1	4	9	16	6	11

* Excluding general plant pests such as the red harvester ant, the fire ant and wireworms.

Eutettix tenellus (Bak.), beet leafhopper.
Garden beet, sugar beet, *Irish potato, radish,* tomato.
Empoasca abrupta DeL.
Irish potato.
Empoasca solana DeL.
Irish potato.
Paratrioza cockerelli (Sulc), potato psyllid.
Irish potato, *tomato.*

COLEOPTERA

Cerotoma ruficornis (Oliv.), bean leaf beetle.
Bean, *watermelon.*
Diabrotica balteata Lec., banded cucumber beetle.
Bean, cantaloupe, lettuce, squash, *turnip,* watermelon, cucumber.
Diabrotica duodecimpunctata (F.). spotted cucumber beetle.
Bean, *sugar beet,* cantaloupe, cucumber, lettuce, *okra,* squash, turnip, watermelon.
Diabrotica trivittata (Mann.), western striped cumber beetle.
Sugar beet, cantaloupe, cucumber, lettuce, squash, watermelon.
Anthrenus verbasci (L.), varied carpet beetle.
Sugar beet.
Agonoderus lineola (F.).
Sugar beet, lettuce.
Phyllotreta pusilla Horn, western black flea beetle.
Cabbage, cauliflower, turnip.
Blapstinus sp., darkling ground beetle.
Cantaloupe, cauliflower, cucumber, lettuce, watermelon.
Ligyrus rubidus Casey.
Lettuce.
Trichobaris mucorea (Lec.), tobacco stalk borer.
Irish potato, tomato.
Aeolus livens (Lec.).
Watermelon.
Wire worms (several unidentified species).

LEPIDOPTERA

Elasmopalpus lignosellus (Zell.), lesser cornstalk borer.
Bean.
Lexostege similalis (Guen.), garden webworm.
Sugar beet.
Estigmene acraea (Drury), salt-marsh caterpillar.
Sugar beet, cauliflower, lettuce.
Laphygma exigua (Hbn.), beet armyworm.
Sugar beet, cauliflower, lettuce, garden pea, sweet potato, tomato.
Feltia annexa (Treit.), granulate cutworm.
Sugar beet, cabbage, lettuce, tomato.
Agrotis malefida Guen., pale-sided cutworm.
Sugar beet, cabbage, lettuce.
Agrotis ypsilon (Rott.), black cutworm.
Sugar beet, cabbage, lettuce, tomato.
Prodenia ornithogalli Guen., yellow-striped armyworm.
Sugar beet, cabbage, lettuce, tomato.
Peridroma margaritosa (Haw.).
Sugar beet, cabbage, lettuce, tomato.
Pieris protodice Bdv. & Lec., southern cabbage worm.
Cabbage.
Autographa brassicae (Riley), cabbage looper.
Cabbage, *cantaloupe,* cauliflower, lettuce, *garden pea, Irish potato, radish, squash, tomato, turnip, watermelon.*
Autographa californica (Speyer), alfalfa looper.
Lettuce.
Autographa biloba (Steph.).
Lettuce.
Plutella maculipennis (Curt.), diamondback moth.
Cabbage, cauliflower.
Hellula undalis (F.), cabbage webworm.
Cabbage, cauliflower.
Diaphania hyalinata (L.), melonworm.
Cucumber.

Phylctaenia rubigalis (Guen.), greenhouse leaf tyer (celery leaf-tyer).
Lettuce.
Heliothis obsoleta (F.) [*Heliothis armigera* (Hbn.)], corn ear worm.
Lettuce, tomato.
Platynota sp.
Lettuce.
Protoparce sexta (Johan.), tomato worm.
Pepper, Irish potato, tomato.
Protoparce quinquemaculata (Haw.), tobacco worm
Pepper, Irish potato, tomato.
Gnorimoschema operculella (Zell.), potato tuber worm.
Tomato.
Gnorimoschema lycopersicella (Busck), tomato pinworm.
Tomato.

DIPTERA

Cecidomyia citrulli Felt, melon gall-midge.
Cantaloupe, cucumber, squash, watermelon.
Hylemyia cilicrura Rond., seed-corn maggot.
Cantaloupe, bean.

HYMENOPTERA

Pogonomyrmex barbatus (F. Smith) vars., the red harvester ant.
Solenopsis geminata (F.), the fire ant.

SUMMARY.—In the foregoing list of insects it will be noted that while the origin and ancient history of many of the forms represented are imperfectly known, it seems probable that some of the species, such as the diamondback moth, the potato psyllid, the beet leafhopper, certain species of grasshoppers, the darkling ground beetle and the tobacco stalk borer are indigenous to the Valley, or the surrounding territory, where they subsisted originally on wild native host plants, whereas it is known that many other species, such as the tomato pinworm, the squash bug, the melonworm and certain species of cabbage worms were introduced during comparatively recent years through the medium of natural dispersion or by artificial carriage.

Table 1 summarizes the numbers of species of insects occurring commonly on the various crops enumerated.

From the data appearing in Table 1 it appears that lettuce, sugar beets grown for seed, and the cole crops cabbage and cauliflower support the greatest variety of insect fauna in the region under discussion, followed closely by tomato and bean.

A total of 73 species of insects not including several unidentified species of wireworms, one species of mite, several species of sowbugs and nematodes, were found attacking 19 different truck and garden crops in the Salt River Valley of Arizona during the period from 1932 to 1937, inclusive.—12-2-38.

Toxicity Studies of So-Called "Inert" Materials With the Rice Weevil and the Granary Weevil*

SHIN FOON CHIU, *Cornell University, Ithaca, N. Y.*

In a previous paper the writer (Chiu 1939) reported the results of toxicological studies of certain "inert" materials and their physiological mode of action upon the bean weevil, *Acanthoscelides obtectus* (Say). The present work is of the same nature except that studies were made on the adults of the rice weevil, *Sitophilus oryzae* (L.), and the granary weevil, *S. granarius* (L.). The "inert" materials used and the methods of experiment and of interpretation of results are essentially the same as described in the previous paper (Chiu 1939), to which the reader is referred for detailed discussions.

Six different so-called "inert" materials, crystalline silica, amorphous silica, magnesium carbonate, bentonite, talc and walnut shell flour were used in these experiments. The insects used in this investigation were reared on wheat grains under an environment of 26–27 degrees C. and 65–70 per cent relative humidity. A group of 120 insects of known age was placed in a 4 by 7 centimeters narrow-mouthed bottle contained 2 grams of the dust material. The bottle was shaken and rotated gently for 1 minute so that the insects were coated heavily with the particles of the material. Then they were transferred to a sieve which was shaken slightly to allow the excess dust to drop off. The food, if it was to be dusted, was treated separately. About 100 grains of wheat were thoroughly mixed and shaken with 2 grams of dust for 2 minutes. After being dusted, the insects were divided

* The author is greatly indebted to Professors T. Roy Hansberry and G. F. MacLeod for their helpful suggestions and criticisms on this paper.

into two groups, one with food (generally 22 grains of wheat were provided for 20 weevils) and another without food. Ten to 20 insects from each group were placed in a stender dish (4.5 by 3 centimeters) covered with a piece of muslin. No excess of dust remained in the container. Twenty to 40 insects taken from the same population were used as checks with or without food as part of each series of tests.

In order to find out how the grain weevils react when they are placed on dusted grains, two more series of experiments were run: (a) normal (untreated) insects on dusted food, (b) dusted insects on dusted food. The former was to simulate the conditions when insects begin to attack grains protected with dust; the latter, the conditions when infested grains are treated with dust, as in actual practice.

In all the tests 60 insects were used for each series. After treatment they were divided into three or six groups. Records were taken separately for each group so that each test was repeated three or six times. Usually the insects were examined once a day for the first 10 days and on alternate days thereafter. Observations were generally discontinued after 30 days. Except during the short time of dusting the insects were kept in the dark, at a temperature of 26–27 degrees C. and a relative humidity of 70–75 per cent.

Unless stated otherwise Abbott's (1925) formula was used for deducting the mortality attributable to natural causes in making calculations of the percentage of mortality. The time-mortality lines were plotted in part according to the method of Bliss (1937) with the ordinate as net percentage of mortality on the basis of probits (probability units) and the abscissas as logarithms of the time of survival after treatment. The lines were fitted by eye to the logarithm-probit points. Each point in the graphs usually represents the mean net percentage of mortality of three samples of 20 insects each or six samples of 10 insects each.

Table 1.—Summarized data on the toxicity of different "inert" materials to the rice weevil.

Material	Treatment	Time Required to Kill, Days*		Slope of the Toxicity Line
		50 Per Cent	100 Per Cent	
Crystalline silica	Insects treated, no food	2.1	4	3.2
	Insects treated, with food	1.8	22	1.2
	Both insects and food treated	1.3	3	2.3
	Normal insects on treated food	3.2	5	5.2
Amorphous silica	Both insects and food treated	4.0	8	3.1
Magnesium carbonate	Insects treated, no food	3.2	6	4.0
	Insects treated, with food	>31.0	>31	—
	Both insects and food treated	2.6	8	1.2
	Normal insects on treated food	5.6	11	—
Bentonite	Insects treated, no food	2.8	6	1.5
	Insects treated, with food	3.4	>30	0.9
	Both insects and food treated	>17.0	>17	—
	Normal insects on treated food	>17.0	>17	—
Talc	Both insects and food treated	13.0	>30	—
Walnut shell flour†	Insects treated, no food	6.2	9	—
Check	No food	6.6	10	—
	With food	>30.0	>30	—

* The time required to produce 50 per cent net mortality was obtained by interpolation from the time-mortality line; the time required to produce 100 per cent mortality was experimentally determined.
† The mortalities in this test have not been corrected by Abbott's formula.

RESULTS OF TOXICITY† STUDIES WITH THE RICE WEEVIL.—Insects 8 to 15 days old (the age is counted from the time the weevil emerged from the wheat grain) were used in all the tests. The results are summarized in table 1 and figs. 1, 2, 3, 4.

† The term toxicity, as used in this paper, does not imply any chemical reaction.

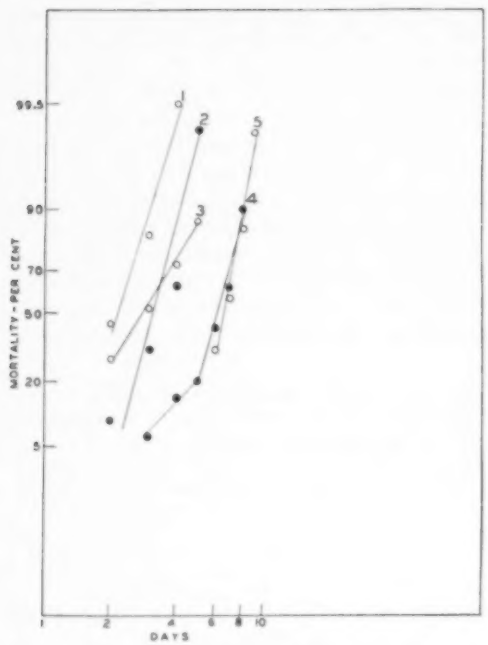

FIG. 1.—Toxicity of different "inert" materials to the rice weevil. No food was provided for the insects. The mortalities on the line for walnut shell flour have not been corrected by Abbott's formula. Curve 1, crystalline silica; curve 2, magnesium carbonate; curve 3, bentonite; curve 4, walnut shell flour; curve 5, check.

The most rapid killing action was obtained when both the insects and food were treated with crystalline silica. For each "inert" material, there is a great difference in mortality between the series with food and without food. The efficiency of the insecticide was invariably higher when the insects were starved after treatment. With the exception of those treated with walnut shell flour, all the treated insects without food died after 4 to 6 days, while some of those with food still survived after 31 days.

With the same material the toxicity varied greatly according to the conditions the insects were subjected to after treatment. With crystalline silica, the order of effectiveness was: Both insects and food treated > insects treated, no food > insects untreated, food treated > insects treated, with food. With magnesium carbonate, the order of effectiveness was: Insects treated, no food > both insects and food treated > insects untreated, food treated > insects treated, with food. With bentonite, the order of effectiveness was: Insects treated, no food > insects treated, with food > both insects and food treated > insects untreated, food treated. It should be pointed out that the untreated insects placed on grains dusted with crystalline silica and magnesium carbonate were not starved to death, because none of the insects in the control (untreated insects without food) died after 5 days. They were undoubtedly killed by the dust which adhered to their bodies when they came in contact with the treated grains.

Walnut shell flour, talc and bentonite had no practical value as insecticides as used against the rice weevil in these tests. Amorphous silica was effective, but its efficiency was much lower than that of the crystalline silica.

Although the conditions were not entirely similar throughout these experiments, the order of effectiveness of these "inert" materials, as compared at 50 per cent mortality and judged by the slope of the time-mortality line, appeared to be: crystalline silica > magnesium carbonate > amorphous silica > bentonite > talc > walnut shell flour.

The conditions of the insects after being dusted may be briefly described. With crystalline silica, 24 hours after being dusted the insects become inactive and

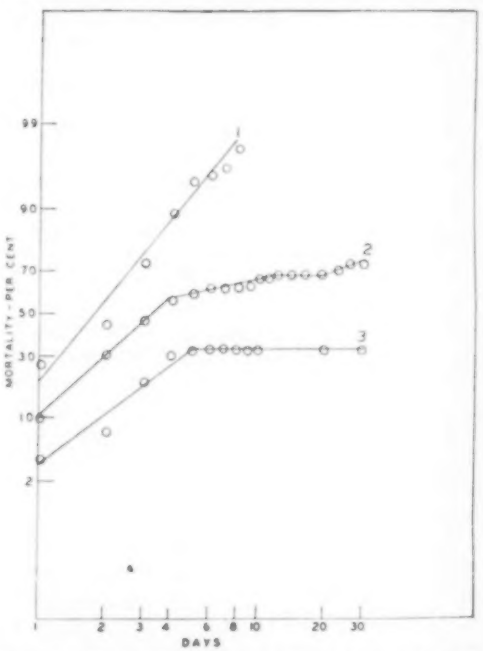

FIG. 2.—Toxicity of different "inert" materials to the rice weevil. The insects were provided with food. Curve 1, crystalline silica; curve 2, bentonite; curve 3, magnesium carbonate.

could not freely crawl around; when food was provided some of them fed a little. The dusted grains were repellent to the weevils. Many weevils spread their hind wings before death, indicating that there was some irritating action. With magnesium carbonate and bentonite, if the insects were transferred to food after being dusted, they fed and cleaned off a large part of the dust adhering to their bodies. The dusted grains were apparently not repellent to the weevils, since both treated and untreated insects fed on them. With amorphous silica, some insects fed on the dusted grains in the beginning of the experiment but stopped feeding 4 or 5 days afterwards. With talc and walnut shell flour, the weevils were active and fed voraciously.

RESULTS OF TOXICITY STUDIES WITH THE GRANARY WEEVIL.—The dust materials used and the conditions in these experiments were similar to those under which the tests for the rice weevil were carried out, except that, with amorphous silica and talc, additional tests were made in which normal insects were put on grains treated with the dust.

The results are summarized in table 2

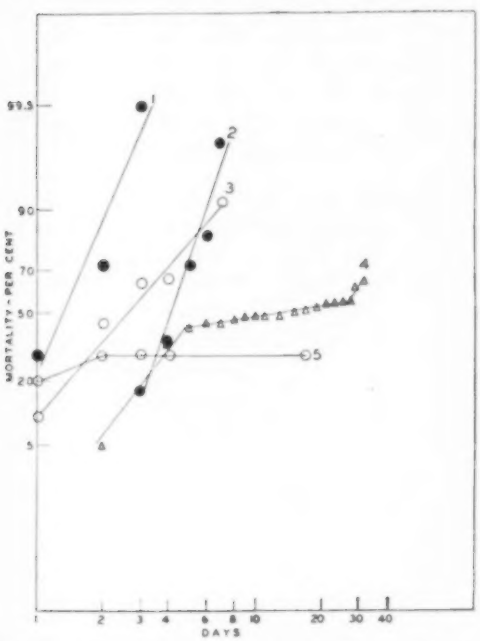

FIG. 3.—Toxicity of different "inert" materials to the rice weevil. Both insects and food were treated with the dust. Curve 1, crystalline silica; curve 2, amorphous silica; curve 3, magnesium carbonate; curve 4, talc; curve 5, bentonite.

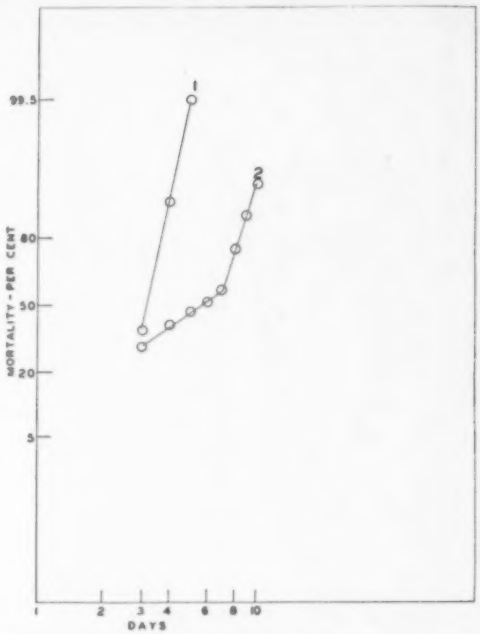

FIG. 4.—Toxicity of different "inert" materials to the rice weevil. Normal insects on dusted food. Curve 1, crystalline silica; curve 2, magnesium carbonate.

and figs. 5, 6, 7, 8. As was the case with the rice weevil, the quickest killing action was obtained when both the insects and food were treated with crystalline silica. Walnut shell flour, talc and bentonite appear to have no practical value as insecticides when mixed with grains infested with the granary weevil. The mortalities of the treated insects were decidedly higher in the series without food than in that with food. According to the conditions under which the insects were kept after being dusted, the order of effectiveness of each material was as follows: For crystalline silica, both insects and food treated > insects treated, no food > insects untreated, food treated > insects treated, with food; for magnesium carbonate, both insects and food treated > insects untreated, food treated > insects treated, no food > insects treated, with food; for bentonite, insects treated, no food > both insects and food treated > insects untreated, food treated > insects treated, with food. It was observed that the insects fed and cleaned off a part of the dust adhering to their bodies when untreated wheat grains were provided.

The order of effectiveness of these "inert" materials under the conditions of

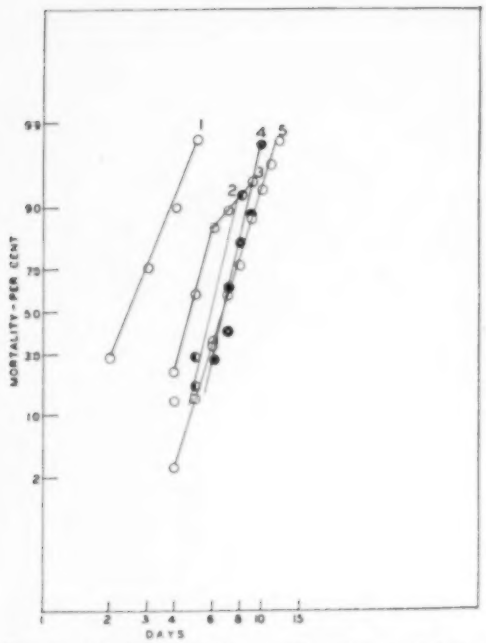

FIG. 5.—Toxicity of different "inert" materials to the granary weevil. No food was provided for the insects. The mortalities on the line for walnut shell flour have not been corrected by Abbott's formula. Curve 1, crystalline silica; curve 2, bentonite; curve 3, magnesium carbonate; curve 4, walnut shell flour; curve 5, check.

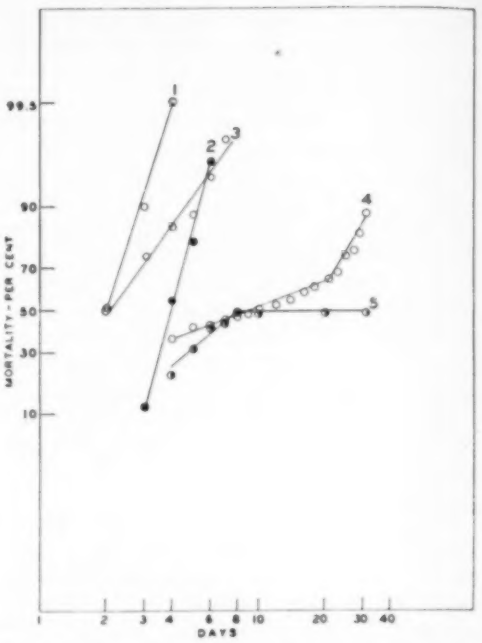

FIG. 7.—Toxicity of different "inert" materials to the granary weevil. Both insects and food were treated with the dust. Curve 1, crystalline silica; curve 2, amorphous silica; curve 3, magnesium carbonate; curve 4, bentonite; curve 5, talc.

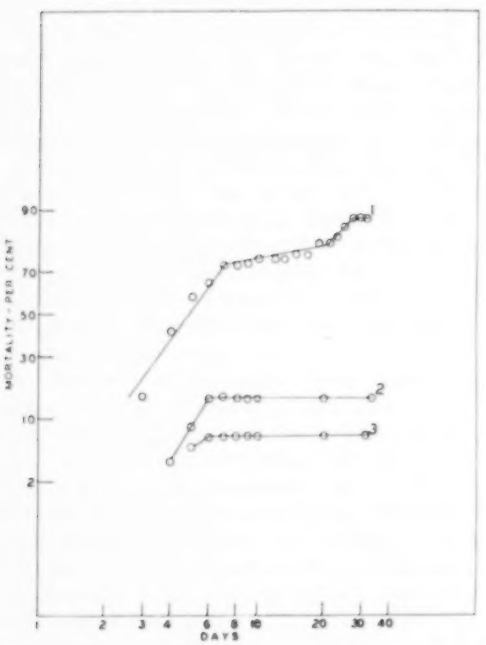

FIG. 6.—Toxicity of different "inert" materials to the granary weevil. The insects were provided with food. Curve 1, crystalline silica; curve 2, bentonite; curve 3, magnesium carbonate.

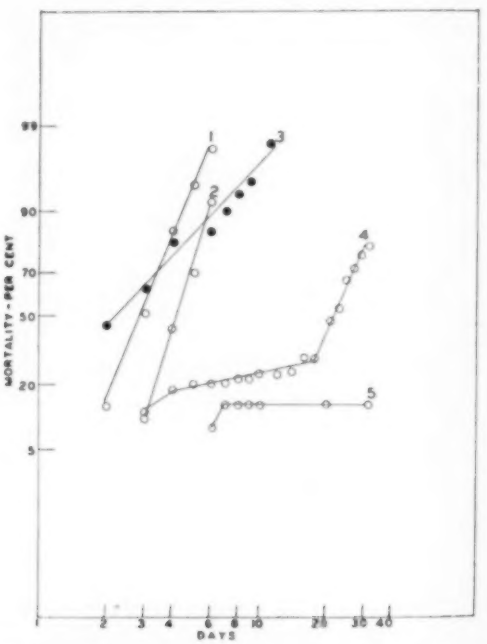

FIG. 8.—Toxicity of different "inert" materials to the granary weevil. Normal insects on dusted food. Curve 1, crystalline silica; curve 2, amorphous silica; curve 3, magnesium carbonate; curve 4, bentonite; curve 5, talc.

Table 2.—Summarized data on the toxicity of different "inert" materials to the granary weevil.

MATERIALS	TREATMENT	TIME REQUIRED TO KILL, DAYS*		SLOPE OF THE TOXICITY LINE
		50 Per Cent	100 Per Cent	
Crystalline silica	Insects treated, no food	2.5	6	2.4
	Insects treated, with food	4.8	>31	—
	Both insects and food treated	2.0	4	3.1
	Normal insects on treated food	2.9	7	2.5
Amorphous silica	Both insects and food treated	4.0	7	3.5
	Normal insects on treated food	4.2	7	3.3
Magnesium carbonate	Insects treated, no food	4.7	10	—
	Insects treated, with food	>31.0	>31	—
	Both insects and food treated	2.1	12	1.4
	Normal insects on treated food	2.2	12	1.0
Bentonite	Insects treated, no food	5.8	9	3.6
	Insects treated, with food	>33.0	>33	—
	Both insects and food treated	9.0	>31	—
	Normal insects on treated food	2.2	>30	—
Talc	Both insects and food treated	>31.0	>31	—
	Normal insects on treated food	>31.0	>31	—
Walnut shell flour†	Insects treated, no food	6.6	11	4.0
Check	No food	6.6	13	2.9
	With food	>33.0	>33	—

* The time required to produce 50 per cent net mortality was obtained by interpolation from the time-mortality line; the time required to produce 100 per cent mortality was experimentally determined.
† The mortalities in this test have not been corrected by Abbott's formula.

these experiments was crystalline silica > magnesium carbonate > amorphous silica > bentonite > talc > walnut shell flour. It is interesting to note that the same results were obtained with the rice weevil, although the granary weevil was comparatively more resistant to the action of these "inert" dusts.

RELATIVE TOXICITY OF DIFFERENT PARTICLE-SIZES OF CRYSTALLINE SILICA.—Three samples of crystalline silica, extra fine, fine, and coarse were tested against the two species of grain weevils. The particle-sizes of these samples were determined by the hydrometer method as proposed by Bouyoucos (1927a, b, 1928). In all these tests both insects and food were dusted with the "inert" material. The results are summarized in table 3 and figs. 9 and 10.

It is evident that the particle-size is an important factor influencing the toxicity of the material. Within a certain range, the toxicity increases as the particle-size

Table 3.—Summarized data on the relative toxicity of different particle-sizes of crystalline silica.

DEGREE OF FINENESS	DIAMETER OF THE PARTICLES, MICRONS		PARTICLES BELOW 10 MICRONS IN DIAMETER, PER CENT BY WEIGHT	SPECIFIC SURFACE, TOTAL SURFACE IN M^2 PER GRAM OF MATERIAL†	*Sitophilus oryzae* TIME REQUIRED TO KILL, DAYS		*Sitophilus granarius* TIME REQUIRED TO KILL, DAYS	
	Range	Average,* in Terms of Surface			50 Per Cent	100 Per Cent	50 Per Cent	100 Per Cent
Extra fine	1–147	2.9	37	0.772	1.3	3.0	2.0	4.0
Fine	1–149	18.8	13	0.119	2.3	5.0	3.7	23
Coarse	10– 74	37.5	0	0.059	5.0	>30	>30	>30
Check					>30.0	>30	>30	>30

* Average diameter in terms of surface,

$$d_{ave} = \frac{1}{\sum \frac{\text{per cent of group of average size particles}}{\text{average diameter of fraction}}}$$

† Specific Surface $= \frac{6}{\text{density} \times \text{average size}}$

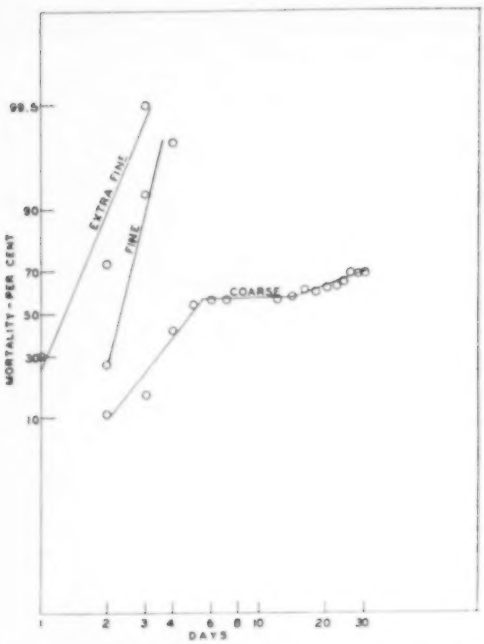

FIG. 9.—The relative toxicity of different particle-sizes of crystalline silica to the rice weevil. (See table 3.) Both insects and food were treated with the dust.

of the material decreases. Crystalline silica having an average particle-size in terms of surface of more than 37 microns in diameter is probably of no value in practical control of these two species of grain weevils.

THE TOXICITY OF CRYSTALLINE SILICA AT DIFFERENT RELATIVE HUMIDITIES.—In order to ascertain the relationship of the amount of water vapor in the air and the efficiency of the "inert" material, observations were made on the toxicity of crystalline silica to the rice weevil at four different relative humidities, *viz.* 0–5 per cent, 25–30 per cent, 75–80 per cent and 95–100 per cent. The insects were kept in a desiccator which contained calcium chloride or known concentrations of sulfuric acid to maintain a certain range of relative humidity. In all the observations the temperature was kept constant at 27 degrees C. Sixty insects were used for each test. No food was provided for the insects after dusting. Untreated checks without food were run with 20 insects taken from the same population as was used for the test.

Figs. 11 and 12 summarize the results obtained. If the relative humidity were expressed in terms of saturation deficiency and plotted against the time required to kill 50 per cent of the insects, the data will give a type of hyperbolic curve, similar to those obtained by Germar (1936) with the granary weevil. It is apparent that the killing effect was much quicker at low relative humidities than at high relative humidities. If the environment were approximately less than 70 per cent saturated, the difference in toxicity under various relative humidities was comparatively slight. But when the relative humidity reached 70 per cent or higher, the efficiency of the dust was markedly decreased. The dust did not, however, entirely lose its insecticidal properties even under 95–100 per cent relative humidity, for it was found that under such humid conditions 20 per cent of the insects in the check were still alive 12 days after the experiment was started, while all the treated insects were dead.

These findings indicate that at least one of the factors contributing to the death of the rice weevil when dusted with crystalline silica is desiccation. It seems logical to consider that the water loss from the body of insects is greatly enhanced

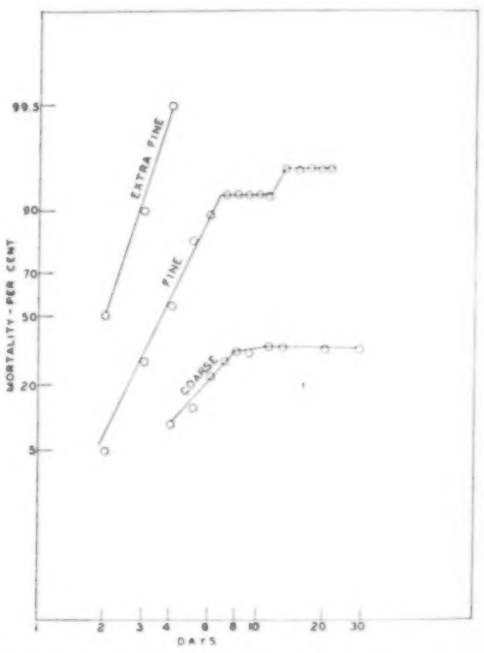

FIG. 10.—The relative toxicity of different particle-sizes of crystalline silica to the granary weevil. (See table 3.) Both insects and food were treated with the dust.

by the surface activities of the enormous number of dust particles which adhere to the integument and that the rate of water loss is a function of the saturation deficiency of the environment.

THE LOSS OF WEIGHT OF DUSTED INSECTS.—In order to obtain further evidence to show that the "inert" dusts have desiccating action on the insect, an experiment was carried out to study the loss of water from dusted insects. The loss of water by evaporation from the insect body was determined by measuring the loss of fresh weight at certain intervals with the assumption that, with a living insect, a fraction of this loss is water. From 20 to 30 insects were used in each series of the experiment. The insects were dusted with three or four different kinds of "inert" materials, and the amount of dust adhering to their bodies was recorded. After being dusted, they were transferred to a weighing bottle which was covered with a piece of muslin. The insects were kept without food in an environment of 27 degrees C. and 70–75 per cent relative humidity. Weighings were made at intervals of 24 hours until all the insects were dead and their weight became constant. An untreated lot of each species was run as a check. The loss of fresh weight of these normal insects in a period of 24 hours was taken as the rate of their metabolism. The ages of the insects used were almost the same as those used for toxicity tests. The granary weevils were 9 to 14 days old, the rice weevils 9 to 15 days old.

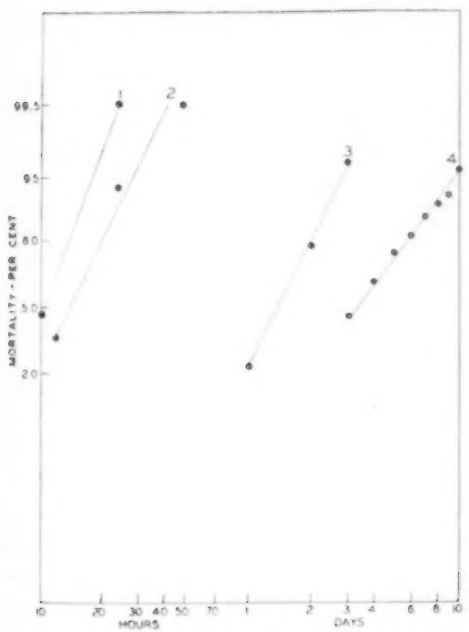

FIG. 11.—The relative toxicity of crystalline silica to the rice weevil at different relative humidities. (No food was provided for the insects after they were dusted.) Curve 1, 0–5 per cent, curve 2, 25–30 per cent, curve 3, 75–80 per cent, curve 4, 95–100 per cent relative humidity.

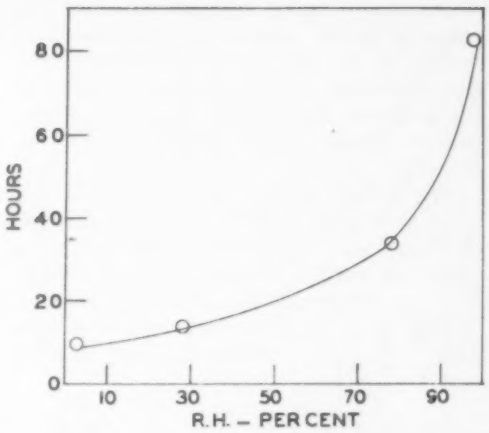

FIG. 12.—The relative toxicity of crystalline silica to the rice weevil at different relative humidities. Abscissa, relative humidity. Ordinate, time to reach 50 per cent mortality.

The results of this experiment are presented in figs. 13 and 14. There is a marked difference in the weight loss between the dusted and untreated insects. When the insects were dusted with effective "inert" materials, the curves for the rate of weight loss are similar in shape for both species. The weight loss of dusted insects was very rapid during the first 2 to 4 days; then it gradually declined until it finally reached zero. The species that rapidly succumbed to the action of the dust lost weight more rapidly. With the normal insects and the insects dusted with walnut shell flour, the weight loss appears to be a linear function of time, and there is no significant difference in the rate of weight loss between them. It is obvious, therefore, that death is concurrent with a loss of water; to conclude that the water loss causes death is a moot question, but a study of the data presented seems to make this conclusion logical.

DISCUSSION.—It is interesting to note that, for all the "inert" materials as used in these tests, the rice weevil was

consistently more susceptible than the granary weevil, a fact that has also been found to be true by Parfentjev (1929) and Shepard and coworkers (1937) in the reaction of the two species to fumigants with the single exception of sulfur dioxide.

The killing action of the "inert" material was much quicker with insects that had no food than with those that were provided with food after the treatment. If it is assumed that the insects were killed by the desiccating action of the dust, this great difference in toxicity water produced by metabolic processes from oxidation of foodstuffs. If an insect is dusted with the effective "inert" material and water is drawn out from the body by means of the surface activities of the fine dust particles, it will invariably die when the amount of water in the body is reduced to below the threshold value; but if the loss is balanced by enough water obtained from the ingestion of food and the amount is maintained above the threshold value, it will survive. Careful observations reveal that the majority of the insects that were highly re-

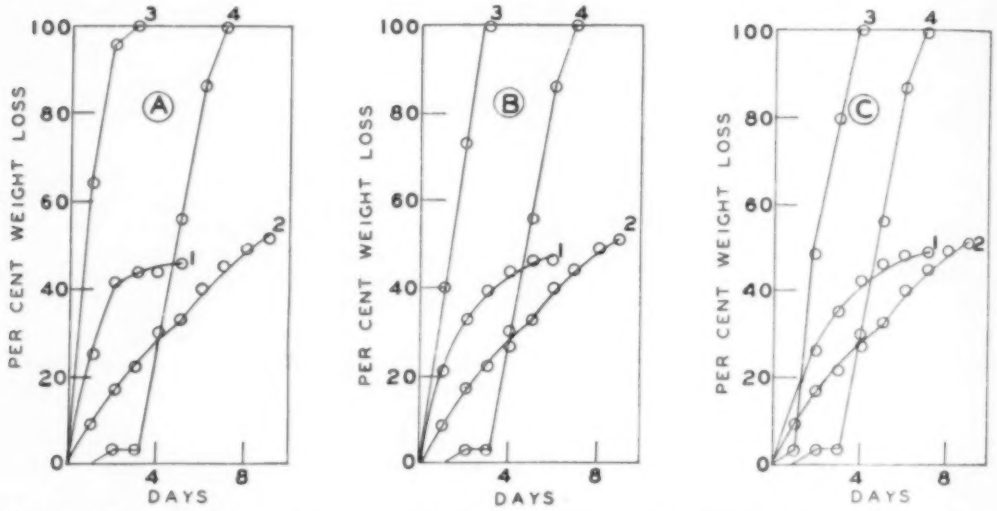

FIG. 13.—Effect of dusting upon the weight loss of the rice weevil. *A*, insects dusted with crystalline silica; *B*, insects dusted with bentonite; *C*, insects dusted with magnesium carbonate. Curve 1, percentages of weight loss of original fresh weight for dusted insects; curve 2, same for untreated insects; curve 3, percentages of mortality for dusted insects; curve 4, same for untreated insects.

due to feeding can be explained on the basis of water metabolism. Water is a fundamental requirement in insect nutrition. The insect can lose a large amount of its fat and protein and yet live, while a loss of a small amount of water may result in death. There is a critical threshold below which water loss cannot go and the insect still recover. For the granary weevil, according to Germar (1936), this threshold is about 30 per cent loss of the total water content of the insect body. For insects that feed on dry materials, a large proportion of the required water is obtained from food. There are two available sources by which an insect can get water from food, one is directly from the water which exists as a component of the food, and another is metabolic

sistant to the action of crystalline silica, amorphous silica, magnesium carbonate and bentonite fed on the food provided. Those that were offered food and were killed by the "inert" material usually suffered so much mechanical irritation from dusting that they were physically unable to feed or failed to find the right place to eat before death.

In regard to the relative practical insecticidal values of these "inert" materials against the two species, crystalline silica is most efficient. Walnut shell flour and talc have very little insecticidal action when used as described in these experiments.

Zacher (1937a, b) and Germar (1936) studied the effects of some of these "inert" materials against stored-product

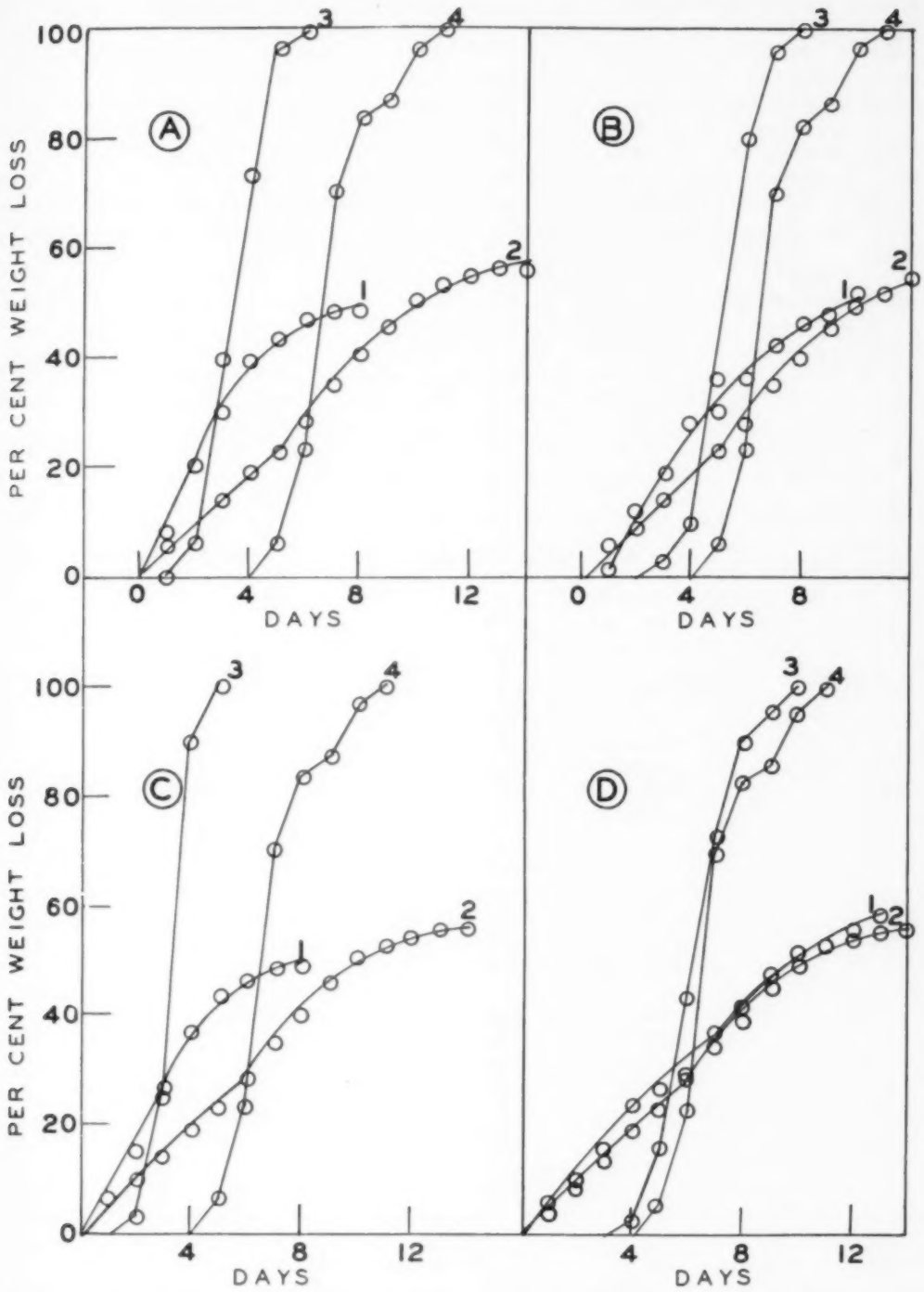

FIG. 14.—Effect of dusting upon the weight loss of the granary weevil. *A*, insects dusted with crystalline silica; *B*, insects dusted with bentonite; *C*, insects dusted with magnesium carbonate; *D*, insects dusted with walnut shell flour. Curve 1, percentages of weight loss of original fresh weight for dusted insects; curve 2, same for untreated insects; curve 3, percentages of mortality for dusted insects; curve 4, same for untreated insects.

insects. Due to the difference in the technique and the quality and quantity of material used in the experiments, as well as the variations in insect population, it seems inadvisable to compare in detail their results with those obtained by the writer. Suffice it to state that, in general, with crystalline silica higher insecticidal efficiency was obtained by these investigators than the writer was able to demonstrate.

An examination of the time-mortality curves presented in this paper reveals two interesting points in the statistical treatment of the data. First, the respective mortality curves are seldom parallel; many of them cross between the points of 30 and 100 per cent mortality. It is true that the most precise estimate of the time of survival from a time-mortality curve is that made at the point of 50 per cent kill, but this is sometimes an unsatisfactory basis for determining the relative practical values of insecticides. In discussing the practical application of these "inert" materials, it seems best to utilize the slope of the time-mortality line and a point near 100 per cent mortality. In other words, the whole mortality curve should be carefully studied before the final decision on the application of an insecticide is reached. Second, in many cases the net percentage of mortality expressed on the basis of probits does not increase proportionally with the logarithm of the time of survival throughout the entire range. In a case of the reaction of the granary weevil to bentonite, fig. 5, a better fit to the time-mortality data is obtained by the use of two straight lines than by one; in a case of the reaction of the rice weevil to talc, fig. 3, the data seem best fitted by three straight lines; and in a case of the reaction of granary weevil to crystalline silica, fig. 6, the data seem best fitted by four straight lines. The fact that a linear relation does not hold between the time of survival measured logarithmically and the probits is usually interpreted as a change of the reaction of the insect population to the poison or a change of the nature of the poison itself. However, an explanation of the real cause of these changes is not indicated by the available data in this investigation.

Studies on the loss of weight of insects seem to indicate that insects dusted with effective "inert" materials lost water much more rapidly than normal insects. There are three ways by which an insect may lose its water: (1) by excretion, water eliminated as waste products, (2) by respiration, water evaporated from the spiracles and (3) by direct evaporation from the surface of the body. The rice and the granary weevil feed on comparatively dry materials and are highly adapted to conserve water in their bodies. A very considerable fraction of the total water loss from dusted insects most probably takes place via the body surface, for the elimination of water through excretion is definitely restricted, and the respiration of dusted insects was found to be normal (Chiu 1939). Therefore, it is believed that the fine particles of the "inert" material, by means of their surface activities, draw water out from the integument of the body, which constitutes the most important action contributing to the death of the insect.

The effect of desiccation, however, cannot be taken as the only physiological mode of action of the "inert" materials, for it is found that the materials do not entirely lose their toxicity even under an environment of 95–100 per cent relative humidity. From this fact and actual observations on the movements of insects after being dusted it is evident that the "inert" dust, besides serving as a desiccating agent, undoubtedly exerts some direct mechanical action on the insect.

SUMMARY.—Laboratory experiments showed that certain so-called "inert" materials, when applied as a dust, are effective against the rice and the granary weevil. Six different "inert" materials were tested. Crystalline silica was most effective, magnesium carbonate, amorphous silica, bentonite, talc and walnut shell flour were less effective in the order named. Within a certain range, there is a definite correlation between toxicity and particle-sizes of the crystalline silica dust, higher insecticidal efficiency being obtained with finer particles. The relative humidity of the environment is an important factor influencing the toxicity of the crystalline silica dust. The killing effect is much quicker at low relative humidities than at high relative humidities. It was found that insects dusted with effective "inert" materials lost weight very rapidly, which is assumed to be

mainly due to the loss of water from the body. Based on observations of (1) the loss of weight of dusted insects, (2) the difference in insecticidal efficiency of the "inert" material when used against insects provided with food and without food and (3) the toxicity of the "inert" material at saturated atmosphere, it is believed that the insects are killed by the "inert" materials through desiccation and through mechanical irritation.—3-16-39.

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Insecticide Tests for Bollworm Control During 1938*

J. C. GAINES,† *Texas Agricultural Experiment Station, College Station*

Planters in this section prefer to use arsenicals containing a higher arsenical content than the commercial calcium arsenates for control of the bollworm, *Heliothis obsoleta* (F.). Results of insecticide tests (Gaines 1937; Moreland 1938; Moreland & Bibby 1931; and Moreland & Gaines 1939) have been published on the control of this pest as progress reports of the cooperative project between the U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine, and the Texas Agricultural Experiment Station. Results of these tests have shown that dusting with 8 to 9 pounds per acre of commercial calcium arsenate gave the most effective and economical control, and dusts containing a high arsenical content were no better than calcium arsenate.

Gaines (1938) found that the M.L.D.'s required to kill fifth instar leafworms for several calcium arsenates ranged from 0.12 to 0.72, and the M.L.D. for a mixture of 7½ per cent Paris green and 92½ per cent calcium arsenate was as low as 0.09.

Cage tests (Smith, Scales & Gaines 1938) also indicated that there were considerable differences in the toxicity and effectiveness of calcium arsenates containing different percentages of water-soluble As_2O_5 by the New York method. These laboratory and cage tests indicate that we might expect better control of the bollworm from the dusts containing a high arsenical content, in spite of the fact that the previous field tests have not shown this to be the case.

Additional tests in connection with this cooperative project, made during 1938, for determining the comparative effectiveness of arsenical dusts containing varying amounts of total and water soluble As_2O_5, and As_2O_3, and calcium arsenates containing varying amounts of water soluble As_2O_5, are herein given.

ARRANGEMENT OF PLATS.—Two experiments, a Latin square and a randomized block, were used in these tests, both being located in the same cut of cotton. The Latin square contained 25 plats, each 10 rows wide and 63.5 feet long, or one-

* Technical contribution 503, Texas Agricultural Experiment Station, in cooperation with the Bureau of Entomology and Plant Quarantine, U. S. Department of Agriculture.

† Thanks are due D. F. Martin and R. A. Eads for assistance in obtaining the field notes.

Table 1.—The arrangement of plats in the Latin square for the determination of bollworm injury and yield in insecticide tests at College Station, Tex.

A	*D*	*C*	*B*	*E*
12.0*	7.2	8.4	8.9	4.9
29.43†	36.06	35.76	35.87	41.99
B	*C*	*E*	*D*	*A*
3.3	4.9	5.6	7.5	15.0
33.88	34.49	36.94	33.96	27.50
D	*A*	*B*	*E*	*C*
6.7	11.5	7.1	7.6	7.6
32.69	29.87	37.93	36.88	36.06
C	*E*	*D*	*A*	*B*
7.1	5.0	7.4	12.9	6.9
35.50	33.93	36.62	26.87	34.31
E	*B*	*A*	*C*	*D*
5.5	5.8	13.7	7.2	7.7
31.56	36.63	27.37	31.69	35.18

Treatment Averages

A	*B*	*C*	*D*	*E*
13.0	6.4	7.0	7.3	5.7
28.21	35.72	34.70	34.90	36.26

* The first figure in each plat represents the average percentage injured forms during the dusting period, from five records, July 18 to August 8.

† The second figure in each plat represents the yield in pounds seed cotton on one-thirty-fifth acre.

Table 2.—The arrangement of plats in the randomized block for the determination of bollworm injury and yield in insecticide tests at College Station, Tex.

A	*D*	*B*	*C*
11.1*	8.2	9.2	8.9
30.25†	34.61	29.44	35.06
B	*C*	*D*	*A*
4.6	8.9	6.9	13.2
34.87	37.05	34.62	31.55
D	*A*	*B*	*C*
7.1	12.8	6.6	6.6
39.32	34.50	42.06	40.06
C	*B*	*A*	*D*
8.8	7.6	12.8	7.4
40.94	37.93	30.75	37.05

Treatment Averages

A	*B*	*C*	*D*
12.5	7.0	8.3	7.4
31.76	36.07	38.28	36.40

* The first figure in each plat represents the average percentage injured forms during the dusting period, from four records, July 19 to August 6.

† The second figure in each plat represents the yield in pounds seed cotton on one-thirty-fifth acre.

twentieth acre in size. The randomized block contained 16 plats, each 11 rows wide and 57.7 feet long, or one-twentieth acre in size. The arrangement of the plats in both experiments are shown in tables 1 and 2.

POISON APPLICATIONS.—All dust applications were made early in the morning (5 to 7 a.m.) with a rotary hand gun, while the cotton was wet with dew. Poisons were applied to the treated plats of the Latin square on the following dates: July 9, 14, 19, 23, 25, 27 and August 1. Three of these applications, on July 19, 23 and 25, were washed off by rains within 6 hours after the applications were made. Calcium arsenates were applied to the treated plats of the randomized block on the following dates: July 10, 15, 20, 22, 23, 28 and August 2. Three of these ap-

Table 3.—The chemical analyses and poundages of the different arsenicals used in insecticide tests at College Station, Tex.

TREATMENT DESIGNATIONS	TREATMENTS	AVERAGE AMOUNT APPLIED PER PLAT ONE-TWENTIETH ACRE, OUNCES	CHEMICAL ANALYSIS*			
			Total As_2O_5	Water Soluble As_2O_5†	Total As_2O_3	Water-Soluble As_2O_3†
Latin square						
A	Untreated					
B	Calcium arsenate–Paris green (93–7)	7.4	41.28‡	7.6‡	—	—
C	Armyworm poison	7.8	42.8	8.6	3.3	2.2
D	Special sample *A*	7.5	38.5	7.9	3.3	2.2
E	Special sample *B*	8.0	36.8	0.8	4.0	2.7
Randomized block						
A	Untreated					
B	Calcium arsenate	7.7	43.5	0.47	—	—
C	Calcium arsenate	7.9	44.5	4.3	—	—
D	Calcium arsenate	7.7	45.1	10.8	—	—

* Analyses made by Division of Insecticide Investigations, Bureau of Entomology and Plant Quarantine, U. S. Department of Agriculture.

† New York method.

‡ Analysis of only the calcium arsenate used in the mixture. The Paris green was not analyzed.

Special samples were supplied through the courtesy of Niagara Sprayer and Chemical Co.

plications, on July 20, 22 and 23, were also washed off by rains. The kind and average amount of dust each plat received in both experiments are shown in table 3. All plats in both experiments received an application of calcium arsenate, applied by airplane on August 8, for leafworm control.

or one-thirty-fifth acre, of each plat in the Latin square; and from the seven middle rows 51.8 feet long, or one-thirty-fifth acre, of each plat in the randomized block.

RESULTS.—The average bollworm injury and yields are shown for each plat of both experiments in tables 1 and 2.

Table 4.—The analysis of variance of bollworm injury (equivalent angles) and yield both with and without the check plats in insecticide tests at College Station, Tex.

	Check Plats Included			Check Plats Omitted		
Source of Variation	Degrees of Freedom	Equivalent Angles for Percentages Bollworm Injury, Mean Square	Yield, Mean Square	Degrees of Freedom	Equivalent Angles for Percentages Bollworm Injury, Mean Square	Yield, Mean Square
Latin Square						
Total	24	9.10	13.21	19	2.82	5.43
Rows	4	1.62	8.50	4	3.35	4.77
Columns	4	5.33	5.90	4	4.82	8.86
Treatments	4	42.50‡	53.65‡	3	3.58	2.64
Remainder	12	1.72	3.74	8	1.27	5.08
Randomized Block						
Total	15	6.32	14.94	11	2.25	12.14
Blocks	3	1.61	32.51	3	3.44	32.69
Treatments	3	24.16‡	30.35‡	2	2.25	5.66
Remainder	9	1.94	3.94	6	1.66	4.02

‡ Highly significant.

BOLLWORM INJURY.—Bollworm injury records were made by counting 100 squares and 100 bolls on consecutive plants in each plat and recording the percentage of injured forms (squares and bolls). These records were made on July 18, 22, 28 and August 2 and 8 on the Latin square; and on July 19, 25 and August 1 and 6 on the randomized block. An average of these records, during the dusting period, for each plat in both experiments is shown in tables 1 and 2. Bollworm egg population records were also made at regular intervals on each plat for use in determining when to make applications of poison.

YIELD.—The total number of plants were counted on the picking area, one-thirty-fifth acre, of each plat. The average numbers of plants on each group of plats receiving the same treatment were as follows: *A*, 450; *B*, 438; *C*, 410; *D*, 444; *E*, 432 on the Latin square; and *A*, 454; *B*, 424; *C*, 460; and *D*, 454 on the randomized block. These records indicate that the difference in stand was not large enough to affect the yields. The yields, pounds of seed cotton, were obtained from the six middle rows 60.5 feet long

It will be noted that each treatment was replicated five times in the Latin square and four times in the randomized block. Equivalent angles were used in making the analysis of variance instead of the percentages of bollworm injury. Since practically all the observed percentages and all the treatment mean percentages were in the extreme range, less than 15 per cent, it is sound procedure, according to Bliss (1937), to transform the percentages to angles before analyzing the data. The analyses of variance for bollworm injury and yields of both experiments with and without check plats are shown in table 4.

A valid estimate of the experimental error can be made when a treatment, in this case check, is omitted. It is legitimate (Yates 1936) to lay out a Latin square with checks and omit them in the analysis. This procedure, at least, eliminates the possibility of check plats influencing the size of the error.

In the analysis of the Latin square with check plats included, it will be noticed that the mean square for treatments as indicated by both equivalent angles for percentage injury and yields was highly

significant. However, the injury or yields were not significantly different when the data were analyzed without the check plats. These analyses show that the only differences that were significant were those between the insecticide treatments and the checks, all the insecticides being equally effective in controlling the bollworm.

In the analysis of the randomized block with the check plats included, the mean square for treatments as indicated by both equivalent angles for percentage injury and yields was highly significant. There were no significant differences, however, in the yields or injury in the analyses in which the check plats were omitted. These analyses show that the only differences that were significant were those between the calcium arsenates and the checks, all the calcium arsenates being equally effective in controlling the bollworm.

SUMMARY.—The two experiments were not in the same set-up or analyzed together, but it is obvious from a comparison of the injury and yield records that all the insecticides, calcium arsenate–Paris green (93–7), armyworm poison, samples *A* and *B* and the three calcium arsenates, were equally effective in controlling the bollworm. These tests do not alter the previous results that calcium arsenate applied at the rate of 8 to 9 pounds per acre is effective and is the most economical control for this pest.—1-20-39.

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Control of the American Strawberry Leaf Roller, *Ancylis fragariae*, in the Lower Missouri River Valley*

PAUL G. LAMERSON and RALPH L. PARKER, *Kansas Agricultural Experiment Station, Manhattan*

The study of the biology and control of the American strawberry leaf roller, *Ancylis fragariae* Walsh & Riley, was continued through the season of 1938† on the George Meunch farm at Blair and on the Department of Entomology experimental plot at Wathena.‡ The season of 1938 began with ample moisture conditions throughout April, May, June and part of July. From July 15 to November 1, there was a marked deficiency of rainfall, resulting in late plants having poor root systems. Such plants, it was believed, would probably bear little fruit during the 1939 season. The plants formed during the early season period of ample moisture conditions, it was thought, would probably produce a normal crop of berries. Seasonal conditions were in general favorable for the development of the strawberry leaf roller.

SEASONAL DEVELOPMENT AND ABUNDANCE OF INSECT.—Adult leaf roller moths were noted in the field March 29.

* Contribution No. 468 of the Department of Entomology, Kansas Agricultural Experiment Station.

† Parker, Ralph L., and Paul G. Lamerson, Biology and control of the strawberry leaf roller, Proc. VII International Congress of Entomology, Berlin, Germany, August, 1938. (In press.)

‡ Support for this work has come from Projects Purnell 187, Hatch 187 and Northeast Experiment Fields No. 9. Mr. Otto Wenger assisted in the field work. Dr. W. T. M. Forbes, Cornell University, determined the insects.

Table 1.—Fall American strawberry leaf roller populations, October 4, 1938.

Owner and Location of Plot	Age of Plants in Years	Number of Larvae Per Square Foot										Total Number of Larvae in 10 Square Feet
		1	2	3	4	5	6	7	8	9	10	
Collin Schuler, Wathena	1	5	3	3	3	4	6	6	4	2	11	47
Dan Moskau, Wathena	2	0	1	1	3	1	1	1	1	0	0	9
Frank Aberle, Blair	1	2	2	3	3	10	5	10	7	8	6	56
George Meunch, Blair	1	2	2	2	2	3	0	4	1	5	2	23
Kansas Agricultural Experiment Station, Department of Entomology, Wathena (Unsprayed)	2	13	4	11	8	9	9	11	16	10	12	103
Collin Schuler, Wathena (Unsprayed)	1	21	24	30	27	15	23	29	12	18	19	218

Unseasonably warm weather resulted in comparatively early emergence. This brood was a week or 10 days in advance of average conditions. First hatch of leaf roller larvae was noted April 23, and the first rolled leaf was noted May 1 or about 1 week after the first larvae appeared.

Heavy infestations in most of the Doniphan County strawberry region resulted in severe damage to many fields of berries. Foliage injury was the worst observed in several years.

The eggs, in general, were deposited on the leaves located nearest the ground. This situation hindered the work of reaching the larvae on the undersides of the leaves with contact sprays.

Examination of larvae, reared to obtain pupation records, indicated that 10 per cent of the overwintering larvae were parasitized.

First-brood leaf roller moths began to emerge June 6. By June 11 the hatch of larvae from eggs laid by first-brood moths was well under way. Damage to berry plants from second-brood strawberry leaf roller larvae was not nearly so severe as that by the first-brood larvae.

Second-brood leaf roller moths began to emerge about July 12. Developmental progress of the first part of this brood was hindered by 2 weeks of high temperatures. When temperatures moderated, coincident with rains, the hatch of leaf rollers increased. The third brood was only one-fifth as numerous as the first brood.

A partial fourth brood of strawberry leaf roller began to appear about August 25 and continued emerging throughout September and the first half of October. Mild fall weather contributed to the further build-up of population of strawberry leaf roller in the berry fields of Don-

Table 2.—Insecticides used in control tests, 1938. Liquid insecticide measurements are expressed in pints or quarts per 50 gallons of water. Dusts were applied at the rate of 50 pounds per acre.)

Treatment
Rotenone* dust, 1.0% rotenone
Rotenone* dust, 0.75% rotenone
Pyrethrum* dust, 0.8% pyrethrins
Pyrethrum* dust, 0.5% pyrethrins
*Stimtox A** dust, 0.5% pyrethrins
Pyrethrum extract† ½ pint plus *Verdol* summer emulsion oil 1 quart
40% nicotine sulfate‡ ½ pint plus *Verdol* summer emulsion oil 1 quart
40% nicotine sulfate‡ ½ pint plus *Superla*§ summer emulsion oil ½ quart
40% nicotine sulfate‡ ½ pint plus *Orthol K*** summer emulsion oil 1 quart
50% free nicotine‡ ¼ pint plus *Superla*§ summer emulsion oil 1 quart
50% free nicotine‡ ½ pint plus *Superla*§ summer emulsion oil 1 quart
40% nicotine sulfate‡ ½ pint plus *Karaya Gum 1AXS*†† 13 ounces
40% nicotine sulfate‡ ½ pint plus *Karaya Gum 1A*†† 13 ounces
Lead arsenate 1½ pounds plus National Oil Products Company (*NOPCO*) soluble neutral fish oil 1 quart
Kalo ‡‡ 2 pounds plus *NOPCO* oil 1 quart

Chemicals were furnished by the following companies:
* John Powell and Company, Inc.
‡ Tobacco By-Products and Chemical Corporation.
§ Standard Oil Company (Indiana).
** California Spray-Chemical Corporation.
†† Jacques Wolf and Company.
‡‡ The Kalo Company.
† Pyrethrum extract was in all cases a stock solution made by extracting 20 pounds of powdered pyrethrum flowers in 1 gallon of a light petroleum oil carrier.

Table 3.—Weather conditions prevailing during American strawberry leaf roller spray applications at Blair Kan., 1938.

Date Applied, 1938	Insecticides Used	Weather		Brood
		Sky Condition	Temperature, Degrees F.	
April 26	Nicotine and pyrethrum sprays	Clear, 15–18 mile wind	78	First
April 30	Rotenone and pyrethrum dusts	Clear, 15–18 mile wind	80	First
May 1	Nicotine and pyrethrum sprays	Cloudy 15–18 mile wind	83	First
May 5	Rotenone and pyrethrum dusts	Cloudy	72	First
May 6	Nicotine and pyrethrum sprays	Cloudy	65	First
May 9	Rotenone and pyrethrum dusts	Clear 15–18 mile wind	63	First
June 14	Nicotine and pyrethrum sprays	Clear, no wind	70	Second
June 19	Metallic sprays and organic dusts	Partly cloudy	85	Second
June 25	Organic dusts	Cloudy, unsettled	79	Second
June 27	Metallic and organic sprays	Cloudy	68–73	Second
June 30	Organic dusts	Clear, 15–18 mile wind	83	Second
July 22	Metallic and organic sprays	Clear, 4–7 mile wind	85	Third
July 27	Metallic and organic sprays	Clear	92	Third
August 1	Metallic and organic sprays	Clear, 4–7 mile wind	94	Third
August 2	Organic dusts	Clear, 25–28 mile wind	90	Third
August 6	Organic dusts	Cloudy, followed by heavy rain	72	Third
August 8	Organic dusts	Clear	92	Third

Table 4.—Summary of 1938 insecticidal control of American strawberry leaf roller larvae in the early stage before rolling of leaflets (unrolled leaflets, larvae 1 to 7 days old).

Treatment and Dosage in 50 Gallons of Water	Percentage of Dead Larvae (100 Larvae Used) After Insecticide Application*			Average Number and Percentage of Killed Larvae (Based on 200 or 300 Larvae Used) After Insecticide Application	
	First Brood	Second Brood	Third Brood	Three Generations	
	Per Cent	Per Cent	Per Cent	Number	Per Cent
50% free nicotine ½ pint plus *Superla* oil 1 quart	99.5	97	92	288.5	96.2
40% nicotine sulfate ½ pint plus *Superla* oil 1 quart	96.0	95	92	283.0	94.3
40% nicotine sulfate ½ pint plus *Verdol* oil 1 quart	90.5	96	92	278.5	92.8
40% nicotine sulfate ½ pint plus *Orthol K* oil 1 quart	98.5	91	88	277.5	92.5
50% free nicotine ¼ pint plus *Superla* oil 1 quart	87.5	94	91	272.5	90.8
Pyrethrum extract† ½ pint plus *Verdol* oil 1 quart	89.5	89	66	245.5	81.8
				Second and third generations	
Lead arsenate 1½ pounds plus *NOPCO* oil 1 quart	—	97	78	175.0	87.5
Kalo 2 pounds plus *NOPCO* oil 1 quart	—	92	87	184.0	92.0
40% nicotine sulfate ½ pint plus *Karaya gum 1A* 13 ounces	—	96	81	177.0	88.5
40% nicotine sulfate ½ pint plus *Karaya Gum 1AXS* 13 ounces	—	97	78	175.0	87.5

* First brood, check based on the number of square-foot readings necessary to count 100 larvae.
Second brood, check based on the number of square-foot readings necessary to count 50 larvae.
Third brood, check based on the number of square-foot readings necessary to count 50 larvae.
† Pyrethrum extract was in all cases a stock solution made by extracting 20 pounds of powdered pyrethrum flowers in 1 gallon of a light petroleum oil carrier.

phan County in the fall of 1938. A population potentially dangerous to the berry plants in the spring of 1939 was present throughout the county.

A 1938 fall survey of the leaf roller population in sprayed and unsprayed plots under observation is recorded in table 1. The lowest infestation was found to be in the more carefully sprayed fields.

METHODS.—Plots, which were 1 rod long, included four adjacent rows of strawberry plants. The series of plots were randomized throughout the four adjacent rows of plants which made a strip extending the length and through the center of the berry field.

The square-foot counts to obtain the first-brood control data were repeated as many times as necessary to count 100 larvae. These counts were made on the untreated part of the berry field. The number of square-foot counts necessary to count 100 live larvae was used as an arbitrary number for the necessary number of square-foot counts to be used on all sprayed plots in the test. Second- and third-brood check areas were chosen in the same manner except that the number of square foot areas was only enough to account for 50 larvae instead of 100 larvae.

Data were recorded under the following headings:

1. Leaflets rolled and unoccupied. 2. Leaflets occupied, larvae alive. 3. Leaflets occupied, larvae dead. 4. Total larvae present. 5. Number rolled leaflets to each square foot.

All sprays were applied at 5-day intervals for three applications, the first of which was applied as soon as the first hatched larvae of each of the broods appeared. The insecticides used in the work are listed in table 2.

Table 5.—Summary of 1938 dust insecticide control of American strawberry leaf roller larvae in the half-grown to mature stage after rolling of leaflets (rolled leaflets, larvae 10 days and older).

TREATMENT AND DOSAGE AT THE RATE OF 50 POUNDS PER ACRE	PERCENTAGE OF DEAD LARVAE (100 LARVAE USED) AFTER INSECTICIDE APPLICATION*			AVERAGE NUMBER AND PERCENTAGE OF KILLED LARVAE (300 LARVAE USED) AFTER INSECTICIDE APPLICATION	
	First Brood	Second Brood	Third Brood	Three Generations	
	Per Cent	Per Cent	Per Cent	Number	Per Cent
Pyrethrum dust, 0.8%† pyrethrins	100.0	99.5	91	290.5	96.8
Pyrethrum dust, 0.5% pyrethrins	97.5	98	94	289.5	96.5
Stimtox A dust, 0.5% pyrethrins	98.5	96	94	288.5	96.2
Rotenone dust, 1.0%	84.5	96	92	272.5	90.8
Rotenone dust, 0.75%	83.5	91	83	257.5	85.8

* First brood, check based on the number of square-foot readings necessary to count 100 larvae.
Second brood, check based on the number of square-foot readings necessary to count 50 larvae.
Third brood, check based on the number of square-foot readings necessary to count 50 larvae.
† Pyrethrum dust in 1938 could not be obtained stronger than 0.8 per cent pyrethrins.

Dates and weather conditions prevailing at the time the sprays were applied are recorded in table 3.

CONTROL.—The effect of the application of various insecticides during the various broods is indicated in tables 4 and 5.

The effectiveness of control was computed and based on the number of living larvae left after each insecticidal application, *i.e.*, the total number of living larvae recorded after the required number of square-foot readings had been made.

The larvae remaining alive after a specific treatment should be a more constant index than the number of rolled leaves since not all rolled leaves are occupied by larvae.

SUMMARY.—The insecticide tests for the control of American strawberry leaf roller during the season of 1938 appeared to indicate the following:

1. Nicotine sulfate 40 per cent, or 50 per cent free nicotine in combination with

summer oil emulsion, proved to be the most effective insecticide when applied during the time interval between the first hatched larvae and the first rolled leaves. This effectiveness held true for all three broods when sprays were timed correctly and applied three times at 5-day intervals.

2. Beginning with the second brood of strawberry leaf roller, lead arsenate sprays, or cryolite sprays in combination with National Oil Products Company neutral soluble fish oil, gave control equal to nearly 40 per cent nicotine sulfate or 50 per cent free nicotine sprays. To obtain best results, these sprays had to be timed for broods and applied often enough to protect newly unfurled foliage.

3. A strong pyrethrum dust (0.8 per cent) appeared to be the most effective remedy after the leaves were rolled. This dust appeared to be 96.8 per cent effective against larvae in rolled leaves.—2-23-39.

Lead Arsenate Combinations and Nicotine Combinations as Control Measures for the Codling Moth, 1938*

PAUL G. LAMERSON and RALPH L. PARKER, *Kansas Agricultural Experiment Station, Manhattan*

The entomological staff of the Northeast Kansas Experiment Fields continued the comparative tests of certain insecticide combinations as substitutes for lead arsenate in spraying for the control of the codling moth during the season of 1938. These insecticide combinations were compared with the non-astringent lead arsenate used alone for control purposes. Previous progress reports of codling moth control for the years 1933, 1934, 1935, 1936 and 1937 appear in the Forty-Second, Forty-Third, and Forty-Fourth Biennial Reports of the Kansas State Horticultural Society.

The tests were conducted at Blair, in Doniphan County, in the Blair experimental orchard of the Northeast Experiment Fields of the Kansas Agricultural Experiment Station.† The apple variety used for the tests was Jonathan. The set of fruit varied from less than 250 fruits per tree to over 1,900 fruits per tree.

METHODS AND PROCEDURE.—Three single-tree replicates were used for each insecticide or combination of insecticides that was tested. The replicates were selected at random on nine rows in the experimental orchard.

Recording of dropped apples began July 7 and continued until harvest time under the classifications wormy, stung and clean. The harvest-time count was preceded by a heavy "Jonathan drop." All of these pre-harvest drops were counted and scored. The harvest count, classified as indicated, was based on 250 apples per tree. Fruits in excess of 250 were counted but not scored for worm defects.

Lead arsenate at the rate of 4 pounds to 100 gallons of water was applied uniformly to all trees in all the plots in the calyx spray. In all the oil combination sprays, the oil was omitted from the calyx and first two cover sprays. Oil was omitted from the last two cover sprays to minimize residue-removal problems. Seven cover sprays were applied to the lead arsenate and the lead arsenate–oil combination spray plots. Eight cover sprays were applied to the nicotine plots.

CLIMATIC CONDITIONS AND SPRAY INJURY TO FOLIAGE, SPRING AND SUMMER, 1938.—Frequent light showers during May and June russeted the Jonathan crop. This russet could not be charged to lime sulfur burn because the condition prevailed over the whole county. Jonathan foliage received a severe setback from an early-season freeze that caused the epidermis of the primary leaves to become ruptured and cracked, and resulted in early-season arsenical burn to leaves of this variety. Climatic conditions during the season were such that it was not safe to use Bordeaux mixture, and only one such spray was applied to the plots. Nicotine compounds which were used as insecticides were not compatible with Bordeaux since the lime in the Bordeaux causes an immediate volatilization of the nicotine. Later infection of "frog-eye," "yellow leaf," or "black rot,"

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Sphaeropsis malorum Peck made additional lesions on the leaves which resulted in further arsenical burn and defoliation. Under such conditions, damage to foliage from various spray materials was difficult to evaluate.

During the season of 1938, the only outstanding damage to foliage resulting from application of spray materials occurred on the various plots to which soybean flour was applied. Damage resulting, by July 15, in complete defoliation of the upper halves of all trees in the test was caused by the use of crude soybean flour at the rate of 4 pounds of soybean flour with 4 pounds of lead arsenate to 100 gallons of water. Refined soybean flour (*Sprasoy*), used at the rate of 1 pound to 4 pounds of arsenate of lead to 100 gallons of water, resulted in heavy damage and about 50 per cent defoliation, but the damage was not so severe as that resulting from the use of crude soybean flour. Fruit from all trees in these plots did not reach normal size, remained undercolored and did not ripen before harvest.

Foliage of all nicotine plots appeared superior in quality and abundance to that of all lead arsenate and oil combination spray plots. Excellent prevention of leafhopper injury was had on all nicotine plots. The control of leafhopper injury was more effective on the nicotine sulfate–Orthol-K oil plots than it was on the plots sprayed with the fixed nicotines.

SEASONAL CONDITIONS AND CODLING MOTH ABUNDANCE DURING THE SEASON OF 1938.—The moth from the overwintering generation of larvae began to emerge April 30. Emergence was 2 weeks in advance of that of the 1937 season. Following this early emergence, cool rainy weather delayed the developmental progress of the codling moth during the interval between May 4 and May 14. Heaviest damage from the first brood occurred during the interval June 6–11. The duration of this brood ranged from April 30 until June 30, when the initial first-brood adult was noted.

Emergence of first-brood moths proceeded at a moderate rate during early July. The interval July 3–11 was one of rather extreme temperatures. It was too hot for much progress by the codling moth. Damage from larvae of the first part of the second brood was very light. August 1–14 was the interval of greatest fruit damage by larvae of the second brood.

Appearance of second-brood codling moth adults began about August 20, and catches of moths from this brood pursued a rather erratic course of lows and highs throughout August and September.

Worm damage by the third brood was the heaviest experienced for several years. Fresh worm-entries could be noted in fruit throughout September and part of October.

SEASONAL DAMAGE.—An abundant carryover of larvae into the spring of 1938 from the previous season's heavy fruit crop (1937), in combination with a light to medium set of fruit, gave the forecasted result: a crop heavily damaged by worms. Dealers in spray materials reported a lighter sale of spray materials (1938) than for several previous seasons. Financial losses from the previous season's heavy crop made economy necessary in the purchase of spray materials. Under such conditions, satisfactory commercial control was limited to those few growers with adequate finances to carry on a full spray program.

Table 1.—Quantities and kinds of insecticides used in control tests, 1938, expressed in pounds per 100 gallons of spray mixture.

TREATMENT
Lead arsenate alone 4 pounds
Lead arsenate 4 pounds plus Verdol 1 quart
Lead arsenate 4 pounds plus Superla 1 quart
Lead arsenate* 3 pounds plus *Petrocide** ½ gallon
Lead arsenate 4 pounds plus *Orthol K* oil 1 quart
Lead arsenate 4 pounds plus soybean flour 4 pounds
Lead arsenate 4 pounds plus *Sprasoy*† 1 pound
Botano-N‡ 5 pounds plus *Orthol K* oil‡ ½ gallon
40% nicotine sulfate§ 1 pint plus Wyoming bentonite 5 pounds plus *Soyoil* 1 quart plus *Dreft* ½ ounce
40% nicotine sulfate§ 1 quart plus *Orthol K* oil‡ ½ gallon
Black Leaf 155§ 8 pounds, first cover spray. Second through fifth cover, *Black Leaf 155* 6 pounds plus ½ gallon National Oil Products Company neutral soluble fish oil (*NOPCO*) Sixth through eighth cover, *Black Leaf 155* 4 pounds plus ½ gallon National Oil Products Company neutral soluble fish oil (*NOPCO*)

The chemicals were furnished by the following companies:
* Latimer-Goodwin Chemical Company.
† Glidden Company.
‡ California Spray-Chemical Corp.
§ Tobacco By-Products and Chemical Corp.

MATERIALS AND DOSAGES.—The insecticide tests for codling moth control in 1938 were restricted to four nicotine

Table 2.—Summary of picked apple counts, September 12–14, 1938, and percentage of wormy, stung and clean fruit.

Treatment, Per 100 Gallons	Replicate	Total Number Apples Per Plot	Apples Wormy			Apples Stung			Apples Clean			Total Number Apples Season Crop
			Number Per Tree	Number Per Plot	Per Cent	Number Per Tree	Number Per Plot	Per Cent	Number Per Tree	Number Per Plot	Per Cent	
Lead arsenate alone 4 pounds	1		28			79			143			
	2		50			85			115			
	3	647	30	108	16.7	35	199	30.7	82	340	52.6	1,761
Lead arsenate 4 pounds *Verdol* 1 quart	1		13			36			201			
	2		19			57			174			
	3	750	23	55	7.3	58	151	20.1	169	544	72.6	1,718
Lead arsenate 4 pounds *Superla* 1 quart	1		5			50			195			
	2		35			37			137			
	3	577	18	58	10.0	26	113	19.6	74	406	70.4	2,456
Lead arsenate 3 pounds *Petrocide* ½ gallon	1		21			63			166			
	2		9			67			174			
	3	750	30	60	8.0	68	198	26.4	152	492	65.6	2,551
Lead arsenate 4 pounds *Orthol K* oil 1 quart	1		21			54			175			
	2		50			75			126			
	3	750	15	86	11.5	33	161	21.5	202	503	67.0	2,981
Lead arsenate 4 pounds Soybean flour 4 pounds	1		7			44			199			
	2		19			60			171			
	3	750	25	51	6.8	62	166	22.1	163	533	71.1	2,927
Lead arsenate 4 pounds *Sprasoy* 1 pound	1		16			59			175			
	2		17			31			202			
	3	750	35	68	9.1	33	123	16.4	182	559	74.5	2,466
Botano-N 5 pounds *Orthol K* oil ½ gallon	1		71			34			145			
	2		41			20			189			
	3	622	80	192	29.0	1	55	8.3	81	415	62.7	1,529
40% nicotine sulfate 1 pint Bentonite 5 pounds *Soyoil* 1 quart *Dreft* ½ ounce	1		66			13			140			
	2		120			6			124			
	3	719	71	257	35.7	24	43	6.0	155	419	68.3	1,706
40% nicotine sulfate 1 pint *Orthol K* oil ½ gallon	1		47			49			154			
	2		29			28			193			
	3	558	37	113	20.2	11	88	15.8	70	357	64.0	3,742
*Black Leaf 155** *NOPCO* oil ½ gallon	1		66			18			166			
	2		72			30			148			
	3	750	74	212	28.3	16	64	8.5	160	474	63.2	2,974

* See table 1 for dosage.

combinations and seven non-astringent lead arsenate combinations with summer oil emulsions and soybean flours.

Information for spray dates was obtained from bait traps located in an orchard adjacent to the Blair experimental orchard. Through a cooperative arrangement with the entomological staff of the Northeast Kansas Experiment Fields, the Doniphan County Farm Bureau informed growers concerning spray dates and also furnished each grower with a weekly summary of moth catches listed for each day of the preceding week. The codling moth spray schedule for 1938 at the Blair experimental orchard was as follows:, Calyx on April 28, first cover on May 10, second cover on May 24, third cover on

Table 3.—Comparative percentages of clean apples, 1938. Percentages of clean dropped apples during summer, pre-harvest and clean picked fruit per plot.

TREATMENT, PER 100 GALLONS	JULY 7–AUG. 5		AUG. 23–SEPT. 5		SEPT. 12–14		SEASON TOTAL	
	Per Cent Clean Summer Dropped Fruit Per Plot	Rank	Per Cent Clean Pre-harvest Dropped Fruit Per Plot	Rank	Per Cent Clean Picked Fruit Per Plot	Rank	Per Cent Clean Season Dropped and Picked Fruit Per Plot	SEASON RANK
Lead arsenate 4 pounds *Sprasoy* 1 pound	89.4	1	85.2	1	74.5	1	81.3	1
Lead arsenate 4 pounds *Verdol* 1 quart	71.1	5	79.1	4	72.6	2	74.1	5
Lead arsenate 4 pounds Soybean flour 4 pounds	85.4	3	82.2	3	71.1	3	78.2	2
Lead arsenate 4 pounds *Superla* 1 quart	85.9	2	78.4	5	70.4	4	75.8	4
Lead arsenate 4 pounds *Orthol K* oil 1 quart	83.5	4	84.1	2	67.0	5	76.6	3
Lead arsenate 3 pounds *Petrocide* ½ gallon	68.7	7	78.2	6	65.6	6	71.0	6
40% nicotine sulfate 1 pint *Orthol K* oil ½ gallon	58.0	9	62.0	9	64.0	7	62.3	8
*Black Leaf 155** *NOPCO* ½ gallon	49.7	10	59.7	10	63.2	8	60.1	10
Botano-N 5 pounds *Orthol K* oil ½ gallon	60.7	8	63.7	8	62.7	9	63.0	7
40% nicotine sulfate 1 pint *Bentonite* 5 pounds *Soyoil* 1 quart *Dreft* ½ ounce	44.6	11	45.9	11	58.3	10	51.3	11
Lead aresenate 4 pounds alone	69.4	6	70.5	7	52.6	11	61.8	9

* See table 1 for dosage.

June 2, fourth cover on June 13, fifth cover on July 5, sixth cover on July 13, seventh cover on July 29 and the eighth cover for the nicotine plots only on August 19.

RESULTS.—Data of the various insecticide tests for the control of codling moth in the Blair experimental orchard at Blair, Kan., are recorded in tables 2 and 3.

Analyses of arsenic residue were made on samples of applies from the lead arsenate plots before and after washing. Results are shown in table 4.

DISCUSSION.—The season of 1938 had frequent and ample rainfall during May, June and the first half of July. From July 20 until October 25 was a period of subnormal rainfall.

The frequency of early spring and summer rains demonstrated the superiority of lead arsenate–oil spray combinations over lead arsenate and water. The lead arsenate–oil combinations were also superior in controlling codling moth when compared with any of the nicotine combinations. The nicotine combinations held up well during the first- and second-brood cover sprays. The nicotine plots showed serious infestation just previous to and following the last cover spray, August 19. From August 19 until harvest

Table 4.—Residue analysis of lead arsenate spray plots, 1938.*

INSECTICIDE	GRAINS ARSENIC (As_2O_3) PER POUND OF APPLES
Before Washing	
Lead arsenate alone	0.012
Lead arsenate plus *Superla*	0.0137
Lead arsenate plus *Verdol*	0.0139
Lead arsenate plus *Sprasoy*	0.0152
Lead arsenate plus *Petrocide*	0.0155
Lead arsenate plus *Orthol K* oil	0.0165
Lead arsenate plus soybean flour	0.018
After Washing	
Lead arsenate plus *Petrocide*	0.006
Lead arsenate alone	0.0061
Lead arsenate plus *Orthol K* oil	0.0065
Lead arsenate plus *Superla*	0.0075
Lead arsenate plus soybean flour	0.0076
Lead arsenate plus *Sprasoy*	0.0082
Lead arsenate plus *Verdol*	0.0083

* Residue analyses were made by Dr. B. L. Smits of the Department of Chemistry, Kansas State College.

time, September 12, the control gradually becomes less effective in the nicotine plots. All lead arsenate–oil combination sprays proved superior to the nicotine combination sprays.

Only two insecticide combinations under test throughout the season held their respective identical rankings in the percentage of clean fruit produced in dropped and picked fruit, when the percentages were grouped in the order of their effectiveness (see table 3). Factors which influenced such tests were as follows: Not all trees dropped their defective apples at the same time; and the effectiveness in control of various dosages and insecticides decreased at different rates and intervals of time.

SUMMARY.—The apples from all lead arsenate plots after being washed were below the arsenic tolerance of 0.01 grain per pound of apples. Samples of apples from the nicotine plots did not show the presence of nicotine at the time of harvest.

Lead arsenate alone ranked lowest in effectiveness during this season of frequent early-season rains. Lead arsenate–oil combinations proved superior to any of the nicotine combinations.

The five high ranking combinations tested, arranged in the order of their effectiveness, were:

1. Lead arsenate plus *Sprasoy*
2. Lead arsenate plus *Verdol*
3. Lead arsenate plus soybean flour
4. Lead arsenate plus *Superla*
5. Lead arsenate plus *Orthol K* oil

Combinations of lead arsenate with a summer oil emulsion or a soybean flour produced better control of codling moth during this season of normal or nearly normal rainfall than did the nicotine combinations.

Combinations of soybean flour* and lead arsenate produced severe injury to leaves and fruit.—2-23-39.

* It has been recommended (Farrar & Flint 1938 and Flint & Farrar 1938) since the close of the 1938 growing season that soybean flour be used at the rate of one-fourth pound to 100 gallons of water.

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Spray Experiments for the Control of the Elm Leaf Beetle

CLIFFORD E. HOOD,* *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine*

The elm leaf beetle, *Galerucella xanthomelaena* (Schr.), is one of the most serious insect enemies of the American elm, *Ulmus americana* L. The adults, which appear first in the season, perforate the leaves with small, irregular holes, and the larvae, which appear later, skeletonize the leaves between the veins, feeding almost entirely on the lower surface and thus causing the foliage to turn brown and fall off.

A total or nearly total defoliation of any tree during a season is injurious in that it reduces its vitality. If defoliation occurs two or three years in succession, it seriously injures or kills the tree, fig. 1. The natural habitat of the elm is moist bottom lands and the borders of streams; hence an abundance of moisture is an aid to the growth and vitality of the tree. Many of the trees planted along the roadsides are located where the moisture conditions are unfavorable, except in seasons of abundant rainfall. Therefore, if total defoliation occurs in a dry season, it is difficult for the trees to refoliate, and their vitality is reduced considerably. For this reason it is often necessary to protect valuable elm trees from a possible defoliation by the elm leaf beetle during periods of outbreaks.

In spraying operations against this insect in New England, dosages of 4 to 8 pounds of powdered acid lead arsenate per 100 gallons of water have been used, and in a number of cases two applications have been made in a season. It was thought that the maximum dosage could be materially reduced, and the necessity of more than one application obviated by the addition of fish oil as an adhesive. To obtain data on these points, control experiments were conducted in 1931, 1932 and 1934.

FIG. 1.—Elm trees at Stratham, N. H., seriously injured by repeated defoliation by the elm leaf beetle.

The condition of the infestation previous to the spraying operations in 1931, 1932 and 1934 was variable. In 1931 from 50 to 60 per cent of the eggs had hatched and many larvae and a few adults were noted on the foliage; feeding was not con-

* The writer is indebted to C. W. Collins, in charge of the Bureau of Entomology and Plant Quarantine laboratory formerly located at Melrose Highlands, Mass., under whose direction the work was conducted, and to C. M. Symonds and L. D. Casey for assistance in conducting the experiments.

Table 1.—Spray experiments against the elm leaf beetle conducted at Stratham, N. H., in 1931.

Date of Treatment	Number of Trees Sprayed	Lead Arsenate, Pounds Per 100 Gallons of Water	Fish Oil Added*	Degree of Treatment	Condition of Trees on July 28
June 19	3	4	Yes	Whole crown	Good
June 19	4	5	Yes	Whole crown	Good
June 20	2	5	Yes	Lower half of crown	Lower half in good condition, upper half entirely defoliated
June 25	3	5	No	Whole crown	Good
Check trees	—	—	—	—	Three-fourths to entirely defoliated

* One-fourth pint per pound of lead arsenate.

spicuous, however, because the larvae were small. In 1932 the infestation was medium to heavy and a few adults and a number of larvae were noted on the foliage. It was estimated that 75 per cent of the eggs had hatched at the time of treatment. In 1934 only adults were noted on the foliage, and very little egg deposition had taken place.

EXPERIMENTS IN 1931.—Late in June, 12 heavily infested elm trees at Stratham, N. H., were sprayed with lead arsenate, some trees with spray containing fish oil (one-fourth pint per pound of lead arsenate) and others with spray containing no adhesive. All the trees were medium to large in size. On 10 trees the entire crown was sprayed and on 2 only the lower half of the crown was treated. In some cities and towns the latter situation occurs, because the spray equipment is not sufficiently powerful to force the spray to the top of the taller trees. Care was taken to treat the undersurface of the foliage, since practically all the larval feeding is done from below.

Table 1 summarizes the data relative to these experiments.

All the fully sprayed trees were in good condition on July 28. Neither adult nor larval feeding had increased noticeably since the trees were sprayed. Only a few pupae were found at the base of these trees.

The two trees sprayed on only the lower half were entirely defoliated on the upper half, fig. 2. Many of the larvae, after consuming the unsprayed portion, migrated to the lower, treated foliage for food, and a number of them, when fully fed, crawled to the base of the trees to pupate. Most of the adults issuing from these pupae undoubtedly migrated to the lower, sprayed portion of the trees to feed. The feeding on the treated portion of these trees was very light, both by larvae and by the new generation of adults coming from the base of these trees or from heavily infested ones nearby. Although only the lower half of these two trees was sprayed, they apparently retained considerable vitality as a result of this protection.

The control was equally good on the trees sprayed with 4 pounds of lead arsenate to 100 gallons of water plus fish oil, and on those treated at the 5-pound dosage of the poison with no adhesive.

The check trees were three-fourths to entirely defoliated on July 28, and large

Table 2.—Spray experiments against the elm leaf beetle conducted at Stratham, N. H., in 1932.*

Number of Trees	Lead Arsenate, Pounds Per 100 Gallons of Water	Fish Oil Added†	Degree of Treatment	Condition of Trees on August 4
4	3	Yes	Whole crown	Good
3	4	Yes	Whole crown	Good
5	4	No	Whole crown	Good
4	2	Yes	Whole crown	Fair to good
3	2	Yes	Lower half of crown	Lower half fairly good; upper half entirely defoliated
Check trees	—	—	—	Three-fourths to entirely defoliated

* All trees were sprayed on June 25.
† One-fourth pint per pound of lead arsenate.

numbers of pupae were found at their bases.

During the first 15 days after the application four light rainfalls were recorded, the total being only 0.38 inch. This precipitation had little or no effect on the spray deposit, even where no adhesive was used. At the end of the season the deposit on the upper surface of the foliage treated with the lead arsenate–fish oil mixture was conspicuous, whereas that on the trees on which no adhesive was used was hardly noticeable. The deposit on the underside of the foliage on all the trees was very conspicuous. From the time of application to July 28 the

FIG. 2.—Elm tree at Stratham, N. H., on which only the lower half of the crown was treated. This portion was well protected, but the upper half of the crown was entirely defoliated. Shortly after this photograph was taken the upper half of the tree was entirely refoliated.

spray deposit had been subjected to a rainfall of 2.33 inches.

EXPERIMENTS IN 1932.—A number of medium-sized to large elms at Stratham, N. H., were sprayed with lead arsenate of different strengths, both with and without the addition of fish oil. As in the previous season, the whole crown was sprayed in most cases, but a few trees were treated only on the lower half.

The data relative to these experiments are summarized in table 2.

The trees fully sprayed with lead arsenate at the rates of 3 and 4 pounds to 100 gallons of water plus fish oil and those treated at the 4-pound rate without an

FIG. 3.—One of the trees at Stratham, N. H., sprayed in 1932 with lead arsenate at the rate of 3 pounds to 100 gallons of water, plus one-fourth pint of fish oil per pound of lead arsenate.

adhesive were in good condition at the end of the season, fig. 3. There was little increase in feeding, by either adults or larvae, after treatment. The 3-pound dosage plus fish oil gave as good results as the 4-pound dosage without an adhesive.

On the trees fully sprayed at the rate of 2 pounds of lead arsenate to 100 gallons of water plus fish oil the increase in defoliation after treatment was much more pronounced, and more pupae were found at the base of these trees. These trees, however, were sprayed just before, or during, a light rainfall, and shortly after the treatment the rain increased in intensity and continued for about 2 hours.

The three trees treated on only the lower half of the crown presented a different aspect. The upper portion was almost entirely defoliated, whereas the lower portion was in fairly good condition, although it showed considerable adult and some larval feeding. A number of pupae were found at the base of these trees.

Table 3.—Spray experiments against the elm leaf beetle conducted at Woburn, Mass., in 1934.

DATE OF TREATMENT	NUMBER OF TREES	LEAD ARSENATE, POUNDS PER 100 GALLONS OF WATER*	INFESTATION	CONDITION OF TREES ON JULY 20
May 28	12	4	Medium to heavy	Good
June 22	9	1	Light to medium	Fair to good
June 22	20	2	Light to medium	Fair to good
June 22	11	3	Medium to heavy	Fair to good
June 22	9	4	Medium to heavy	Fair to good
Check trees	—	—	Medium to heavy	Heavily defoliated

* All sprays contained one-fourth pint of fish oil per pound of lead arsenate.

The check trees were three-fourths to entirely defoliated, and many pupae were found at the base.

EXPERIMENTS IN 1934.—In 1931 and 1932 the earliest date on which the spray operations were started was June 19, when both eggs and larvae, as well as adults, were abundant. In 1933 R. C. Brown, of the Melrose Highlands Laboratory, found from trap records that in eastern Massachusetts the adults began issuing from hibernation about May 1, issuance was at its height about May 16 and was completed about May 25. It was therefore thought advisable to begin some of the spraying operations shortly after issuance was completed, before any, or but little, egg deposition had taken place, and in the 1934 experiments, which were carried out at Woburn, Mass., one group of elms was treated on May 28 for comparison with other groups that were treated at the usual time, June 22.

The data are presented in table 3.

The application of May 28 showed the best control. On the trees receiving this treatment very little adult and practically no larval feeding was noted during the entire season. On July 20 many of the trees sprayed on June 22 showed a much greater amount of adult feeding and a moderate amount of larval feeding. Practically all the adult feeding and some of the larval feeding was done prior to this spray application, but there was some larval feeding after the treatment, since the undersurface of some of the foliage was not reached with the equipment employed. No pupae were found at the base of the trees sprayed May 28, whereas a moderate number was found at the base of those sprayed on June 22. Large numbers of pupae were found at the base of the check trees.

The degree of control in the trees sprayed on June 22 with 1 and 2 pounds of lead arsenate to 100 gallons of water was but slightly less than that obtained in the group treated at the higher rates. This was due partly to a lighter infestation and partly to the fact that it was impossible, with the equipment used, to

Table 4.—Effect of different periods of exposure on toxicity of lead arsenate spray to the elm leaf beetle, Woburn, Mass., 1934.

DATE FOLIAGE WAS SPRAYED	INSECTS PLACED IN TRAY		DEAD INSECTS REMOVED ON JULY—												CONDITION OF INSECTS AT END OF EXPERIMENT
	Number	Date	19	20	21	22	23	24	25	26	27	28	29	30	
Adults															
May 28	100	July 20	—	—	7	23	29	23	13	2	3	—	—	—	All dead
June 22	100	July 20	—	—	14	48	27	5	6	—	—	—	—	—	All dead
Check	100	July 20	—	—	0	0	2	0	0	1	2	—	—	—	95 living
Larvae															
May 28	75	July 18	13	16	15	4	13	1	1	3	3	1	0	1	4 pupae in tray
June 22	75	July 18	5	22	20	6	11	0	3	3	0	2	—	—	3 pupae in tray
Check	25	July 18	0	0	0	0	0	0	0	0	0	0	0	1	All in larval or prepupal stage

reach the undersurface of all the foliage.

To test the toxicity of the treated foliage after different periods of exposure, larvae and adults of the elm leaf beetle in trays were fed foliage sprayed at the 4-pound dosage on May 28 and June 22. Table 4 shows the rate of mortality in these tests.

It will be noted that the kill of adults in the tray containing the late-sprayed foliage occurred significantly earlier than in that containing early-sprayed foliage, although the mortality was complete in both cases. The time of maximum kill was about the same in both trays. The early-sprayed foliage had been subjected to 3.84 inches of rain as compared with 0.88 inch for the late-sprayed foliage.

A few of the larvae in the trays pupated, but this was undoubtedly due to the fact that some of the larvae were large and practically full fed when placed in the trays, or because the undersurface of some of the foliage had not received a deposit of poison.

SUMMARY.—The purpose of these experiments was to determine the minimum dosage of lead arsenate necessary to control the elm leaf beetle, the most favorable time of application and the possibility of eliminating the necessity of more than one treatment. In 1931 and 1932, a few adults and many eggs and larvae were present; also, a moderate amount of adult feeding and some larval feeding was noted on the foliage at the time of treatment. In 1934, a few adults and eggs were noted on the early-treated trees while, on the trees sprayed at a later date, some adults and a number of eggs and larvae were present and a moderate amount of feeding by both adults and larvae was noted at the time of treatment.

In 1931, good control was maintained with a dosage of 4 pounds of lead arsenate to 100 gallons of water, and in 1932 with 3 pounds to 100 gallons of water, both these mixtures containing fish oil as an adhesive. In 1932 the 4-pound dosage without adhesive gave almost the same degree of control as the 3-pound dosage with fish oil. The 2-pound dosage of arsenate, plus fish oil, used in 1932 gave fairly good results on some of the trees, while on others the control was not so good, but in the latter case rain fell before or shortly after the spray treatment was completed. Since this situation might occur at any time during the spraying season, it should be taken into consideration in determining the dosage necessary to give good control.

In 1934 the best control was obtained on the trees treated on May 28 with lead arsenate at the 4-pound rate plus fish oil. This control was due to a considerable extent to the earliness of the spray. Of the trees treated on June 22 with lead arsenate at the rates of 1, 2, 3 and 4 pounds plus fish oil, the 3- and 4-pound dosages showed the best results, being about equally efficient.

RECOMMENDATIONS.—The results of the experiments and observations show that good control of the elm leaf beetle can be obtained with a mixture of 3 pounds of lead arsenate to 100 gallons of water, plus fish oil as an adhesive, which should be applied, if possible, between the time of final issuance of the insect from hibernation (about May 25) and June 10, in the New England States. The application can, however, be extended beyond the latter date if necessary to complete the spray schedule. The early application reduces the adult population to a minimum before much egg deposition has occurred. It also protects the tree for the entire season against adults emerging from hibernation and those migrating from untreated trees, as well as against larvae and the new generation of adults which are abundant in August and which do considerable feeding before going into hibernation. The undersurface of the foliage should be treated as thoroughly as possible, for, although the adults feed through the leaf, the larvae feed almost exclusively on the undersurface, consuming all except the framework and the upper epidermis. Linseed oil can be substituted for fish oil, and either should be used at the rate of $\frac{1}{4}$ pint (4 ounces) to each pound of lead arsenate in the spray tank.

From these and other spray experiments which the writer has conducted over a period of years, he has found that if fish oil or linseed oil is not used an additional pound of lead arsenate is necessary to allow for loss due to rains that might occur shortly after application. When an adhesive is used, no retreatment of the trees is necessary.

In the control of the elm leaf beetle or other insects it is sometimes necessary to

spray shade or fruit trees in proximity to dwelling houses or other buildings. Even when this is done with the utmost care, some of the material may drift upon buildings and, if allowed to dry, would render them unsightly. Spray mixtures containing fish oil can be readily washed from buildings by drenching them with water both before and after the spraying. The final water treatment should be applied promptly, while the spray material is still moist, as the oil dries rapidly after the evaporation of the water.

Since many of the elm trees are very tall, it is almost impossible to reach the top with any solid-stream spray when the velocity of the wind is high. Spray treatments should therefore be timed for favorable conditions. Early in the morning is the best time to treat elms, since at this time it is usually calm and on traveled highways automobile traffic is at a minimum. If the spray equipment has not sufficient power to reach the upper part of the tall trees, it is advisable to treat as much of the trees as possible, as by protecting part against defoliation the loss in vitality is reduced and the recovery of the defoliated portion hastened.

In communities where the elm leaf beetle is destructive, all the valuable street trees should be treated, since elm trees growing on private property which are not treated may act as a source of reinfestation for the protected trees the following season.—3-1-39.

The Hydrogen Ion Concentration of the Digestive Fluids and Blood of the Codling Moth Larva*

JAMES MARSHALL, *Tree Fruit Branch, Washington Experiment Station, Wenatchee*

In the use of insecticides for control of phytophagous insects, comparatively little attention has been paid to the internal environment of the insect. This is particularly true in the case of the larva of the codling moth, *Carpocapsa pomonella* L., concerning the digestive fluids of which there appears to be but scanty information.

It is assumed that alimentary poisons, as employed in codling moth control, become toxic only when in solution, yet either in the interest of persistence of the material, or innocuousness to the fruit tree, it is essential that they be practically insoluble and non-volatile on the surfaces of leaves or fruits. Obviously, then, conditions obtaining within the digestive tract of the codling moth larva must differ greatly from those encountered on the tree.

Probably the most important factors relating to the solubility of poisons in the stomach of an insect are the hydrogen ion concentration of the digestive fluids and the nature of the buffers or soluble salts therein. The experiments reported herewith, which were conducted in 1936 at the Tree Fruit Branch of the Washington Experiment Station, Wenatchee, concern only the hydrogen ion concentrations of the digestive fluids and blood of the codling moth larva.

Because of the fact that, in present methods of chemical control, it is usually the minute, newly hatched larva that is poisoned, attention was directed particularly at the first instar form. Experiments likewise included partially developed larvae, however, for comparison with the more difficult determinations at the former stage of development.

REVIEW OF LITERATURE.—Kirkland & Smith (1898) recognized that the fluid in the alimentary tract of the gypsy moth larva was of importance in the control of this insect by chemicals. They mentioned that it was alkaline to litmus, and surmised that this might result from the presence of basic potassium phosphate.

Jameson & Atkins (1921) reported that the digestive secretions of the silkworm are strongly alkaline (pH 9.0–9.8 in the ventriculus) and noted a buffering effect in the rapidity with which the acid mulberry leaf (pH 5.0) was neutralized after ingestion.

An attempt to correlate arsenical toxicity with hydrogen ion concentration of the insect digestive tract was made by Fulmek (1929). He found that the solubilities of various metallic arsenates and arsenites, in a buffer solution made up to

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pH 9 (roughly corresponding to the pH of the ventriculus of the silkworm), agreed fairly well with their toxicities.

Hoskins & Harrison (1934) studied the buffering power of the ventriculus of the honeybee. They demonstrated that this portion of the alimentary tract is well buffered by two buffer systems, one a phosphate system and the other unknown.

Swingle (1938) studied five species of lepidopterous larvae and found that all had alkaline digestive fluids, whereas five species of leaf feeding beetles had acid digestive fluids. He reported that the predominant anion of the ventriculous of the insects examined was phosphate, and the predominant cation potassium.

Concerning methods in the determination of the hydrogen ion concentration of small amounts of fluid such as are found in insects, Felton (1921) suggested mixing on an opal glass plate a drop of the fluid to be tested with a drop of indicator solution and placing the mixture in close proxmity to several buffer solutions similarly treated.

Crozier (1923) found that semitransparent aquatic chironomid larvae tolerated relatively high concentrations of certain indicator solutions and could be observed under the microscope after ingestion of indicator solution and while still uninjured.

Felton's method (1921) was used by Bodine (1925) in determining the pH of the blood and the alimentary tract of Orthoptera. He reported that, if determinations were made within 1 minute, it was not necessary to exclude air from the droplets of fluid that were to be tested.

Potentiometric determinations of the pH of the alimentary tract of insects were made by Swingle (1930). He figured a modified quinhydrone electrode for testing small drops of fluid, and stated that accurate determinations could be made with a drop of liquid 1 millimeter in diameter. The principle involved in his apparatus was the lowering of a finely drawn-out agar bridge into contact with the drop of fluid which rested on a small platinum plate. This platinum plate, connected to the galvanometer, served as one of the electrodes.

METHODS USED IN COLORIMETRIC DETERMINATIONS.—An adaptation of a procedure suggested for protozoa by Pantin (1923) was used for the colorimetric determinations. Segments of unsprayed apples were placed in glass crystallizing dishes and painted with an alcoholic solution, or suspension of the indicator to be used. A small amount of distilled water was then introduced to restrict the larvae to the treated fruit surface. Next were pinned to the fruits, slips of waxed paper, bearing codling moth eggs on the point of eclosion. After a short time the larvae emerged, crawled to the surface of the fruit and commenced seeking a point of entry. In the course of their crawling or biting at the skin of the fruit, many of them became contaminated with particles of the indicator which were subsequently ingested, sometimes before the larvae had pierced the fruit with their

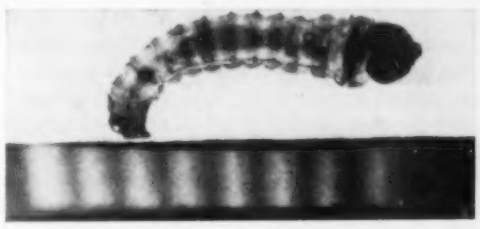

FIG. 1.—First instar larva photographed beside reflected image of color tubes. Alimentary tract colored by cresol red.

mandibles and sometimes after. The most useful of the indicators had apparently no deleterious effects on the larvae, for development was apparently unaffected, at least to the third instar following the ingestion of a sufficient amount of the indicator to produce decided internal coloration, fig. 1.

About an hour or more after the larvae had emerged from the eggs, they were examined by transmitted light under a compound microscope at a magnification of ×25 to ×50.

An estimation of the pH value of the digestive fluid was made by comparing the coloration of the digestive tract, as seen through the light-pervious body wall, to a row of color tubes made up from standard buffer solutions. The tubes, suspended in a small case in a window, were focused sharply in the plane of the object on the microscope stage, by means of an achromatic condenser. Comparison was effected by moving the object (larva) in juxtaposition to the image of the row of

standard tubes until matching was obtained.

METHODS USED IN POTENTIOMETRIC DETERMINATIONS.—The apparatus for potentiometric pH determinations followed Hoskins & Harrison (1934). It consisted of a small platinum electrode attached to the arm of a dissecting microscope and thus freely movable horizontally and vertically. Saturated KCl-calomel was used for the reference electrode. An agar bridge of small bore glass tubing, was finely drawn out to give contact with the drop of test fluid deposited in a small depression in the platinum plate. The potentiometer, a portable instrument, had a sensitivity of 0.5 millivolt.

In the process of making a determination, a droplet of fluid was placed in the median depression of the platinum electrode, a small amount of quinhydrone was added and the electrode was then ratcheted upwards until the droplet came in contact with the pointed tip of the agar bridge. A reading from a drop of standard buffer solution about 1 millimeter in diameter was reproducible within 0.03 pH. Voltage drift caused no difficulty below pH 8.7, but, as would be expected, above this point readings were not consistent.

To measure the hydrogen ion concentration of the digestive tract of codling moth larvae, fourth or fifth instar individuals were taken from infested fruits, then imbedded in warm parafin and dissected to expose the alimentary tract. Blood was removed by applying a small piece of filter paper to the viscera. The digestive fluids were then extracted by puncturing the wall of the alimentary tract with a micro-syringe.

Determinations of the blood were made by puncturing the integument and extracting fluid directly from the body cavity.

RESULTS OF COLORIMETRIC DETERMINATIONS.—In the colorimetric determinations a series of indicators was employed covering the range pH 5.2 to pH 9.8. It included brom cresol purple, brom thymol blue, neutral red, phenol red, cresol red, thymol blue, phenolphthalein and cresolphthalein. Totals of 212 first instar codling moth larvae and 30 third and fourth instar larvae were examined and of these numbers, 59 first instar and 7 fourth instar forms were used with the two most suitable indicators, cresol red and thymol blue.

The pH of the digestive fluids of both first instar and more mature codling moth larvae proved to be above the range of brom cresol purple and brom thymol blue. With phenol red (pH 6.8–8.4) the apparent pH of the ventriculus of first, third and fourth instar forms was about 8.0. Cresol red (pH 7.2–8.8) indicated that the fluids in the ventriculus varied from about pH 8.0 to pH 8.4. With both phenol red and cresol red, however, the color change over the upper 0.5 pH of the range was difficult to detect within the larval alimentary tract. This condition may have been related not only to the characteristics of the indicators but to factors such as frequent faint natural coloration of the larva, particularly after feeding, degree of transparency of the body wall, amount of ingested indicator and amount of ingested food material.

The most satisfactory indicator was thymol blue, which showed a pH of 8.4 to 8.6 for first instar larvae and 8.6 to 8.8 for third and fourth instar forms.

Phenolphthalein and cresolphthalein appeared to be distasteful to the larvae, for few attempted to penetrate apples painted or dusted with these indicators. Since ingested phenolphthalein gave only faint coloration with first instar larvae but definite coloration with fourth and fifth instar larvae (apparently pH 8.6–8.8) it may be that the alimentary tract becomes somewhat more alkaline with approaching maturity. On the other hand, this indicator may be less repellent to the larger individuals. The crop and ventriculus of fourth instar larvae were indicated by cresolphthalein to have a pH of approximately 8.7. Regurgitated fluid varied from pH 8.7 to pH 9.0. No coloration of the alimentary tract of first instar larvae was obtained from cresolphthalein.

Neutral red was unsatisfactory as an indicator for the digestive tract, the range (pH 6.8–ph 8.0) being too low. Two or 3 hours after ingestion, however, it appeared in the epithelial cells of the Malpighian tubules and in the pericardial "nephrocytes." Even after having fed within apples for 11 days and having developed from first to third instar, several active larvae still showed neutral red coloration in these tissues.

Table 1.—Apparent pH values of the alimentary tract of first instar codling moth larvae by colorimetric determination.

INDICATOR	CROP	VENTRICULUS	PROCTODEUM
	Before Entering Fruit		
Phenol red	8.0 plus	8.0 plus	6.7–6.9
Cresol red	8.0–8.4	7.8–8.4	7.0–7.4
Thymol blue	8.4–8.6	8.4–8.6	—
Phenolphthalein	8.4	—	—
	After Entering Fruit		
Phenol red	8.0 plus	8.0 plus	7.8
Cresol red	8.0–8.4	8.0–8.4	—
Thymol blue	8.4–8.6	8.4–8.6	—
Phenolphthalein	—	—	—

Evidently the hydrogen ion concentrations in ventriculus and crop are similar. The proctodeum, however, appeared in general to be somewhat less alkaline though more irregular in reaction than the anterior and mid portions of the alimentary tract. Phenol red and cresol red indicated a variation from pH 6.7 to pH 7.8 in the proctodeum, though only in 15 individuals was coloration of that portion observed.

Electrometric determinations of the juice of apples upon which the larvae were fed showed an active acidity of pH 3.2 to pH 3.3. The titratable acid in 10 milliliters of filtered apple juice required 10 milliliters of tenth normal sodium hydroxide; *i.e.*, 0.6 per cent malic acid equivalent. Despite the decided acidity of the apple juice, however, and despite the fact that the ventriculus distends to over twice its original diameter after a first instar larva has fed within the apple tissue for 4 or 5 hours, the active alkalinity of the digestive tract was not appreciably reduced during feeding. Evidently the digestive secretions of the codling moth larva are strongly buffered, though the nature of the buffer or buffers is not known.

The more reliable colorimetric determinations for first instar larvae are summarized in table 1. Those dealing with later instars are brought together in table 2.

Table 2.—Apparent pH values for third and fourth instar larvae by colorimetric determination.

INDICATOR	pH VALUE OF CROP AND VENTRICULUS
Phenol red	8.0 plus
Cresol red	8.0 plus
Thymol blue	8.6–8.8
Phenolphthalein	8.6
Cresolphthalein	8.5 plus

RESULTS OF POTENTIOMETRIC DETERMINATIONS.—In extraction of the contents of the alimentary canal with a micro-syringe, some difficulty was experienced in obtaining, even from fourth and fifth instar larvae, sufficient material for a potentiometric determination. Because of this, some of the determinations in table 3 represent the combined fluids of both crop and ventriculus, while the remainder represent one or the other of these divisions.

Although the hydrogen ion concentration of the contents of the crop and ventriculus of fourth and fifth instar larvae was outside the general limit of accuracy of the quinhydrone electrode (pH 8.5), no voltage drift was observed up to 3 minutes at pH 8.7, which evidently represented an average condition; but in a few instances regurgitated fluid of pH 9,

Table 3.—pH values of digestive fluids of fourth and fifth instar larvae by the quinhydrone electrode.

LARVA	pH VALUE	REGION SAMPLED
1	8.7	Crop
2	9.0?	Crop
3	8.3	Ventriculus
4	8.8	Ventriculus
5	8.7	Ventriculus
6	8.7	Ventriculus
7	8.7	Crop and ventriculus
8	8.7	Crop and ventriculus
9	8.2	Crop and ventriculus
10	8.8	Crop and ventriculus
11	8.9	Crop and ventriculus
12	9.0?	Crop and ventriculus
13	8.9?	Crop and ventriculus
	Average 8.7	

or above, gave irregular readings with decided voltage drift. It is felt, however, that for the purpose of the investigation this type of electrode was reasonably accurate.

The blood of partially developed and fully developed (fourth and fifth instar) codling moth larvae was found to be slightly acid. The quinhydrone electrode in five determinations showed the hydrogen ion concentration of the blood to be as follows: pH 6.8, 6.7, 6.7, 6.75, and 6.8. Voltage readings were constant up to 3 minutes with all the determinations.

DISCUSSION OF RESULTS.—Present methods for control of the codling moth rely principally on poisoning the larva by arsenicals, fluorine compounds or fixed nicotines, as it seeks to gnaw its way through the epidermis of the apple. Once safely established within the apple it is almost invulnerable except, under certain circumstances, to substances such as nicotine. Since suitable arsenicals or fluorine compounds must be practically insoluble on the surface of the leaves or fruit yet soluble in the digestive tract of the codling moth larva, the internal environment of the larva is of prime importance in the control of this insect.

Swingle (1938), who has experimented at length on the effect of the digestive fluids of insects upon the solubility of arsenicals, is of the opinion the most important single factor in this connection is the hydrogen ion concentration of these fluids. He concludes, "It appears possible to predict the relative order of toxicity of acid lead arsenate, calcium arsenate and magnesium arsenate to chewing insects if the hydrogen ion concentration in the insects' mid-guts are known."

Although no potentiometric method for the determination of the hydrogen ion concentration of the minute alimentary tract of the newly hatched codling moth larva was available, an apparently reasonable approximation was reached by a colorimetric procedure. This procedure indicated a pH value of 8.4 to 8.6 for the crop and ventriculus of the first instar form. The same method, applied to larvae sufficiently large for potentiometric determinations, indicated pH values varying from 8.5 to 8.8. When the larger forms were dissected and the hydrogen ion concentration of the contents of the crop and ventriculus determined potentiometrically it was found to be in the neighborhood of pH 8.7.

From these experiments it seems logical to conclude that the hydrogen ion concentration of the crop and ventriculus of the newly hatched codling moth larva is indeed definitely on the alkaline side and generally between pH 8.4 and pH 8.7.

There appeared to be no significant change in the pH of the alimentary tract of the first instar larva before and after having fed on apple tissue which had an active acidity of pH 3.3 and titratable acid amounting to 0.6 per cent as malic acid; so the digestive fluids must be well buffered.

These characteristics of the internal environment of the codling moth larva may have a practical bearing on the control of the insect by alimentary poisons. For example, a year previous to this investigation, it was determined that a commercial calcium arsenate was about 40 times as readily soluble in the juice of unripe Jonathan apples as was acid lead arsenate. It seemed curious therefore, since the larvae apparently consume a considerable amount of apple juice or tissues soon after entering the fruit, that, particle sizes being equal, the former arsenical should not be distinctly the more toxic; but in well buffered alkaline digestive secretions, the acidity of the fruit juice might be of minor importance. It is possible that in such conditions, as suggested by Swingle (1938), acid lead arsenate was actually more soluble than calcium arsenate. Inasmuch as it has been noted (Marshall 1937) that calcium arsenate agglomerates or particles adhere to the mouthparts of the codling moth larva as readily as lead arsenate, this matter of relative solubilities may explain why calcium arsenate with approximately one-third greater arsenic content than acid lead arsenate has been, pound for pound, no more effective for codling moth control.

SUMMARY.—This paper may be summarized as follows:

1. The hydrogen ion concentrations of the digestive fluids and blood of the codling moth larva were studied.

2. Colorimetric determinations of the crop and ventriculus of first instar larvae agreed reasonably well with those of third to fifth instar larvae, though somewhat more variable. They indicated the hydro-

gen ion concentration of these portions to be in the neighborhood of pH 8.5 in the first instar, and perhaps slightly higher in the later instars.

3. Potentiometric determinations for third to fifth instar larvae indicated an average pH of 8.7, and from this it is assumed the actual pH for first instar larvae may likewise reach 8.7.

4. The alimentary fluids of the codling moth larva are evidently well buffered, though the nature of the buffer or buffers was not investigated. Ingestion of the acid pulp of an unripe apple did not appreciably reduce the active alkalinity of these fluids.

5. The hydrogen ion concentration of the blood of the fourth instar codling moth larva was found to be between pH 6.7 and pH 6.8.

6. The importance of the internal environment of the larva in relation to control by alimentary poisons is briefly discussed.—3-7-39.

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Factors Influencing the Absorption of Sodium Fluoride by the American Cockroach

G. L. HOCKENYOS,* *Springfield, Ill.*

In a previous publication (Hockenyos 1933) the writer presented evidence that sodium fluoride was directly absorbed through the body integument of the oriental cockroach, *Blatta orientalis* L. and that the absorption was greatest in areas of thin, flexible cuticle and least in areas of well sclerotized cuticle. It was also shown that this species of roach did not swallow lethal doses of sodium fluoride in the process of washing the antennae or legs to free them of applied fluoride. The present paper presents data obtained in an effort to discover some of the factors that influence the speed of absorption of sodium fluoride as shown by the length of time required for the absorption of a lethal dose by the American cockroach, *Periplaneta americana* (L.). The experiments were planned to throw light on the following problems: (1) The validity of the hypothesis that the body integument of the American cockroach acts as a semipermeable membrane in so far as the absorption of sodium fluoride is concerned, (2) the internal factors influencing the speed of absorption of sodium fluoride, (3) the external factors influencing the speed of absorption of sodium fluoride.

EXPERIMENTAL METHODS.—Two test methods were used. The first was that of injection with a very small needle of a hypodermic syringe graduated to 0.01 cubic centimeter. In making the injection

* Sentinel Insect Control Laboratory.

Table 1.—Time required for sodium fluoride applied as a contact poison to kill variously pretreated American cockroaches. Five roaches were used in each test.

PRETREATMENT	TREATMENT	EFFECT, TWO HOURS	EFFECT, FIVE HOURS
None	Dusted heavily with sodium fluoride	No effect	All dead
Injected with 0.05 cc. water	Dusted heavily with sodium fluoride	No effect	All dead
Injected with 0.05 cc. 5 per cent Na_2HPO_4	Dusted heavily with sodium fluoride	All seriously affected	All dead
Injected with 0.05 cc. 10 per cent glucose	Dusted heavily with sodium fluoride	All dead	All dead

it was necessary to chill the insects to keep them quiet and so avoid unnecessary injury in handling. The needle was inserted at the junction of the head and thorax and directed caudad just under the dorsal wall and slightly laterad but parallel to the medio dorsal line. In this way the needle did not injure the aorta. The needle was thrust in to bring the point close to the junction of the thorax and abdomen. Amounts of solution up to 0.06 cubic centimeter were used, and checks indicated that this amount of distilled water had no effect whatever on the check lots. About 5 per cent of the roaches probed with the needle but not injected at all died as a result of the treatment.

The second test method was to dust roaches heavily in a quart jar and allow them to crawl into a clean jar where they were kept for observation. Unless otherwise indicated experiments were conducted at room temperature which did not vary much from 72 degrees F. The insects were trapped stock and as nearly as possible represented the last instar before maturity. They averaged 0.75 gram in weight.

EXPERIMENTAL RESULTS.—Preliminary tests indicated that when roaches were injected with a constant volume of 0.05 cubic centimeter of sodium fluoride in water the concentration required to kill at least 80 per cent in 4 hours was 0.4 per cent or 1–250. It was also determined that roaches might be injected with 5 per cent of disodium hydrogen phosphate in distilled water or 10 per cent glucose in distilled water without any apparent harmful effect on them. It was observed that the glucose had a strong stimulating effect and caused the roaches so treated to recover from the cold rigor much more rapidly than those not so treated. Another series of preliminary tests showed that the inclusion of 5 per cent of disodium hydrogen phosphate or 10 per cent glucose with sodium fluoride did not affect the activity of the sodium fluoride when it was injected in lethal or sublethal concentrations. The test recorded in table 1 was made to determine if the injection of 5 per cent disodium hydrogen phosphate or of 10 per cent glucose would influence the rate of absorption through the body integument as shown by the speed of kill.

Since the phosphate and glucose solutions had proved harmless in themselves and had not affected the reaction of the roaches to injected solutions of sodium fluoride, it seems a reasonable supposition that the phosphate and glucose had acted on the body integument as on a semipermeable membrane and served to draw in by osmosis the moisture containing dissolved sodium fluoride from the surface of the body of the roach.

Wigglesworth (1934) in his monograph *Insect Physiology*, page 37, attributes the

Table 2.—Effect of sodium fluoride applied as a contact dust to American cockroaches pretreated by injection with various phosphates of sodium. Five roaches were used in each test.

PRETREATMENT	TREATMENT	EFFECT, TWO HOURS	EFFECT, FIVE HOURS
None	Dusted heavily with sodium fluoride	No effect	No effect
Injected with 0.05 cc. water	Dusted heavily with sodium fluoride	No effect	No effect
Injected with 0.05 cc. 1½ per cent Na_3PO_4	Dusted heavily with sodium fluoride	Almost dead	All dead
Injected with 0.05 cc. 1½ per cent Na_2HPO_4	Dusted heavily with sodium fluoride	Considerable effect	Almost dead
Injected with 0.05 cc. 1½ per cent NaH_2PO_4	Dusted heavily with sodium fluoride	Slight effect	Slight effect

Table 3.—Effect of certain diluents on the speed of action of sodium fluoride applied as a contact poison; 20 per cent sodium fluoride and 80 per cent diluent by weight in each case.

DILUENT	EFFECT, 1 HOUR	EFFECT, 1½ HOURS	EFFECT, 3½ HOURS	EFFECT, 9 HOURS
NaH_2PO_4	None	None	None	Dead
Na_2HPO_4	None	None	None	Considerable
Na_3PO_4	None	None	None	None
Pyrophyllite	None	Considerable	Dead	Dead
Extra light calcium carbonate	None	None	None	None
Heavy calcium carbonate	None	Slight	Considerable	Nearly dead

buffering of the insect blood largely to phosphates and proteins. In table 2 is shown the effect of injecting small amounts of the three phosphates of sodium. The roaches had been kept in a warm dry place overnight to reduce the volume of body fluids. It is interesting to note that the effect of the phosphates was in order of increasing alkalinity.

In the study of the effect of external factors of the absorption of sodium fluoride, the roaches were dusted heavily so that maximum adherence would result. The roaches were then transferred to clean jars for observation. Unless otherwise noted, five roaches were used in each test. The result of the first test on external factors is given in table 3.

It will be noted that the effect of the three phosphates is in the reverse order of their effect when injected. It is interesting to consider that the monosodium phosphate is by far the most soluble and that the other two do not differ greatly in their lower solubility. The different effects of the two calcium carbonates are in the order expected, since the larger individual particles are less likely to prevent the sodium fluoride particles from coming into contact with the roach. Pyrophyllite is a talclike mineral mined in North Caroline. It is remarkable only in that it is difficult to wet. The mixture used in the above test would float on water for a considerable time.

To investigate further the effect of pyrophyllite and see if another water-resistant diluent might have the same effect the tests recorded in table 4 were made.

Roaches preconditioned by being maintained for several hours in either warm saturated or warm dry atmospheres did not show much difference in speed of reaction to sodium fluoride applied as a contact powder.

Roaches injected with minimum lethal doses recovered from the chilling incident to the treatment and died about an hour later. Those receiving greater doses did not recover from the chilling. Those receiving sublethal doses recovered from the chilling, showed partial paralysis for about an hour and then fully recovered.

In the fall of 1936, W. P. Flint and W. E. McCauley mentioned to the writer that the addition of hydrated lime to sodium fluoride greatly accelerated the killing effect of the fluoride, the rapidity of effect at times approaching that of pyrethrum. With their permission the writer has investigated this phenomenon at some length. In the test recorded in table 5, lime was compared with several other diluents for sodium fluoride.

In order to ascertain the most effective

Table 4.—Effect of two hydrophobic diluents on the speed of absorption of sodium fluoride by American cockroaches.

DILUENT	PROPORTION OF DILUENT PER CENT	TIME IN HOURS REQUIRED TO RENDER 8 OUT OF 10 ROACHES HELPLESS
None		4
Pyrophyllite	90.0	1½
Pyrophyllite	92.5	2
Pyrophyllite	95.0	4½
Pyrophyllite	97.5	5
Aluminum stearate	2.5	2
Aluminum stearate	5.0	2

Table 5.—Effect on American cockroaches of several diluents mixed in equal proportions by weight with sodium fluoride.

DILUENT	TIME IN MINUTES TO RENDER 8 OUT OF 10 ROACHES HELPLESS
Calcium carbonate (medium weight)	205
Tricalcium phosphate	190
Hydrated lime (commercial grade)	14
Potassium alum	180
Trisodium phosphate	215

Table 6.—Effect of various ratios of hydrated lime and certain other chemical diluents used with sodium fluoride; 2.1 grams sodium fluoride used in each case. Time indicated is that required to render 8 out of 10 roaches helpless.

Diluent	Amount in Grams	Molar Ratio	Minutes to Render Helpless
Hydrated lime	3.7	1–1	30
Hydrated lime	1.9	2–1	27
Hydrated lime	0.9	4–1	13
Hydrated lime	0.4	8–1	17
Hydrated lime	0.2	16–1	25
Hydrated lime	0.1	32–1	38
Calcium oxide	0.9	4–1	12
Calcium cholride	1.4	4–1	240
Barium hydroxide	4.0	4–1	25

ratio of lime to fluoride various molar ratios were used with the results given in table 6.

These results indicate that the optimum ratio of sodium fluoride to hydrated lime is about two to one by weight and that both calcium oxide and barium hydroxide (crystalline) produce an activating effect similar to that of lime. In order to ascertain whether hydrated lime promoted penetration of the sodium fluoride through the body integument or reacted favorably with sodium fluoride, the experiments described in table 7 were performed.

These data seem to show that lime somehow conditioned the integument of the roaches and that this effect wore off with lapse of time. Lime might condition the roaches' integument by absorbing and possibly reacting with various fats and fatty acids that might tend to inhibit the entrance of any aqueous solution. The experiment described in table 8 was carried out to give some evidence on this point.

Since oleic acid is known to have some toxicity as a contact spray it was deemed advisable to perform the tests described in table 9.

In tables 4 and 5 is evidence that hydrophobic diluents are superior to those that are hydrophilic. Again in tables 8 and 9 is found evidence that at least some of the fats and fatty acids serve as protective agents that tend to reduce the absorption

Table 7.—Pretreatments of chilled American cockroaches prior to being dusted with sodium fluoride. About 10 minutes were required to warm the roaches after pretreatment. Time given is that required to render four out of five roaches helpless.

Pretreatment	Time in Minutes
(1) Hydrated lime applied for 10 minutes and roaches then brushed as free of lime as possible and warmed. Sodium fluoride applied at once.	9
(2) As in (1) but roaches washed in a jet of cold water the more fully to remove the hydrated lime. Roaches warmed. Sodium fluoride applied at once.	13
(3) As in (1) but calcium carbonate used in place of hydrated lime.	more than 120
(4) Roaches chilled and washed in cold water (no hydrated lime used). After being warmed, they had sodium fluoride applied at once.	more than 120
(5) As in (2) but also rinsed in cold, dilute hydrochloric acid to remove lime further. Roaches lively when dusted with sodium fluoride.	10
(6) As in (5), but roaches dusted with sodium fluoride as soon as they began to revive from chilling.	3
(7) As in (6), but calcium carbonate used in place of hydrated lime.	43
(8) As in (5), but 30 minutes allowed to elapse from time roaches revived until they were treated with sodium fluoride.	30
(9) As in (5), but 1 hour allowed to elapse.	50

Table 8.—Pretreatment of American cockroaches with oils and fatty acids prior to being dusted with sodium fluoride. Time given is that required to render four out of five roaches helpless.

Pretreatment	Time in Minutes
(1) Sprayed with 95 per cent ethyl alcohol and, when dry, dusted with sodium fluoride and hydrated lime, 50–50.	10
(2) Same as (1), but talc used in place of hydrated lime.	30
(3) Sprayed with 8 parts alcohol and 2 parts castor oil; when dry, dusted with sodium fluoride and hydrated lime, 50–50.	10
(4) As in (3), but talc in place of hydrated lime.	300
(5) Sprayed lightly with oleic acid alone and then dusted with sodium fluoride and hydrated lime, 50–50.	30
(6) As in (5), but talc in place of hydrated lime.	300

Table 9.—Effect on American cockroaches of oleic acid treatment with and without sodium fluoride. Time given is that required to render four out of five roaches helpless.

TREATMENT	TIME IN MINUTES
(1) Sprayed with 20 per cent oleic acid in alcohol, dried 5 minutes and dusted with talc.	220
(2) Same as (1), but hydrated lime used in place of talc. No effect.	300
(3) Same as (1), but dusted with hydrated lime and sodium fluoride, 50–50.	75
(4) Same as (1), but dusted with talc and sodium fluoride, 50–50.	220

of sodium fluoride through the body integument. In order to throw more light on these apparently contradictory sets of data, the tests described in table 10 were run.

Table 10.—Effect on American cockroaches of certain hydrophobic materials as diluents for sodium fluoride. Time given is that required to render four out of five roaches helpless.

DILUENT	PER CENT	TIME IN HOURS
Pyrophyllite	20	7.00
Pyrophyllite	80	8.00
Aluminum stearate	5	4.75
Aluminum bronze powder	5	4.25
Lampblack	5	12.00
Lycopodium powder	5	2.80

A test was made of the effect of each of the diluents used alone. The pyrophyllite was observed to slow up the activities of the roaches but did not produce any paralysis for 12 hours. The aluminum and *Lycopodium* powders did not seem to affect the insects in the slightest, and it was found that roaches pretreated with *Lycopodium* powder and then treated with sodium fluoride were not killed until 15 hours had elapsed. The aluminum stearate seemed to slow up the roaches but not to the extent that the pyrophyllite did.

In table 11 is shown evidence that sodium fluoride made by different manufacturers may vary greatly in the speed of absorption by roaches and in their relative activation by lime.

The material listed as sample *C* was found to contain 20 per cent of some inorganic material that was insoluble in water. Its exact chemical nature was not determined. This was the sample used in experiments described in tables 5, 6, 7, 8 and 9. In all the other tables the material was from the lot represented by sample *B*. Since there was so much difference in the samples made by different manufacturers the problem of making sodium fluoride in the laboratory by various methods was undertaken. The speed of absorption varied greatly according to the method of manufacture and to a lesser extent with different batches made by the same method. These data are not yet ready for publication. The desirability of knowing if there existed a relation between the activating effect of lime on sodium fluoride and the temperature of the roach led to an experiment in which the temperature of the roaches was controlled for the duration of the tests to within 1 degree plus or minus. The results are given in table 12.

When the data of table 12 are plotted it is found that the three figures given as the killing time for fluoride alone constitute a straight line.

DISCUSSION.—The factors influencing the rate of absorption of sodium fluoride by the American roach are doubtless

Table 11.—Comparison of the speed of absorption, by American cockroaches, of sodium fluoride made by three different manufacturers. Time given is that required to render four roaches out of five helpless.

	MATERIAL	TIME IN HOURS
Sample *A*	Easily wet by water. Colored blue with a copper compound.	20.00
	Same plus 50 per cent hydrated lime by weight.	17.00
Sample *B*	Easily wet by water. White.	10.00
	Same plus 50 per cent hydrated lime by weight.	1.00
Sample *C*	Very resistant to wetting by water. White.	7.00
	Same plus 50 per cent hydrated lime by weight.	0.75

numerous and involved. The writer's previous work indicated that sodium fluoride is absorbed directly through the integument, and from the data herewith presented it would seem that the integument acts as a semipermeable membrane and is the seat of osmotic forces that influence the rate of diffusion of sodium fluoride into the body. Ramsey (1935) made a study of the rate of evaporation of water from the American roach and gave particular attention to the observation of Gunn (1933) that at a certain temperature, in the neighborhood of 30 degrees C., the evaporation rate went up very suddenly. Ramsey was able to show that droplets of water placed on the sclerites of cockroaches persisted much longer than those placed on the wings of cockroaches or on glass surfaces at temperatures below 30 degrees C. By microscopic examination of droplets of water on sclerites, he found that they were covered by a film, possibly of a waxy nature, which accounted for retardation of evaporation. At 30 degrees C. this film was found to undergo a change of phase associated with a greatly increased permeability to water molecules. The data of the present paper can best be explained by assuming the presence of such a film on the surface of the American cockroach.

Table 12.—Effect of temperature on the rate of absorption, by American cockroaches, of sodium fluoride when used with and without hydrated lime. The fluoride is sample *B* of table 11. Time given is that required to render four out of five roaches helpless.

Treatment	Time in Minutes at		
	15 Degrees C.	25 Degrees C.	35 Degrees C.
Sodium fluoride alone	430	280	160
Sodium fluoride 2 parts plus hydrated lime 1 part	95	35	35

SUMMARY.—The body integument of the American roach is found to have the properties of a semipermeable membrane coated with a film of water-resisting fat or oil. The rate of absorption of sodium fluoride is influenced by the osmotic force exerted by the body fluid and by various factors that act upon the oil film. These factors are temperature and chemicals that either absorb or react with the film. —3-14-39.

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Observations on the Biology of *Saperda tridentata* Oliv. and *Magdalis armicollis* Say (Coleoptera)

CLARENCE H. HOFFMANN, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine*

A study of the biology of two common elm insects—the elm borer, *Saperda tridentata* Oliv., and the red elm bark weevil, *Magdalis armicollis* Say—was undertaken to determine whether their habits, with special reference to feeding and oviposition, might enable them to serve as inoculation agents of the Dutch elm disease fungus, *Ceratostomella ulmi* (Schwarz) Buisman. The transmission studies with these two species, which are being conducted cooperatively by members of the Morristown, N. J., laboratory of the Bureau of Entomology and Plant Quarantine and the Bureau of Plant Industry, U. S. Department of Agriculture, are still

in progress and are hence not yet reported.

SAPERDA TRIDENTATA.—The literature pertaining to *Saperda tridentata* is voluminous, as indicated by the extensive bibliography in the monograph of the genus *Saperda* by Felt & Joutel (1904) and the many papers listed in the several issues of the *Index to the Literature of American Economic Entomology* since the publication of this monograph. While due cognizance is made of the literature, no attempt will be made to summarize it here. The scope of this paper is to present additional observations on controversial points and to record other data that are apparently new.

The larvae of this beetle work in the inner bark and sapwood of elm and, if abundant, girdle the branches and the trunk and cause the death of the tree. There is still considerable question as to whether this species is a primary or secondary pest of elm trees. The writer is of the opinion that it usually attacks devitalized wood, but admits having seen the species occasionally in apparently healthy tissue. Because of their nocturnal habits, the adults are seldom observed under natural conditions.

Adults of this species begin to emerge in New Jersey about the middle of May and continue to issue throughout the summer. Of 1,588 adults that issued from a number of felled trees collected in one locality and kept in an outside screened cage, 10 per cent emerged in May, 50 per cent in June, 36 per cent in July and 4 per cent in August. During the flight period the adults occasionally fed on elm leaves, chewing into the midrib and destroying the larger lateral veins. Caged individuals fed on leaves and on the bark of young elm twigs but seldom penetrated to the xylem.

Mating occurred a week or two following emergence, after which the females began egg deposition. Under insectary conditions at Morristown, late in the spring and in the summer seven pairs mated for an average of 140 minutes (minimum 42, maximum 190). Caged adults supplied with elm foliage lived from 4 to 50 days.

Contrary to most writings, some of which are recent, the eggs of *Saperda tridentata* are deposited in, rather than on, elm bark. The female seeks a crevice in the bark and spends about 2 minutes making an incision with the mandibles. Then she reverses her position and inserts the ovipositor in the incision, eventually reaching the inner bark, where she deposits from one to three eggs in a few minutes. Most of the eggs are inserted a short distance into the inner bark, but some are more deeply embedded and occasionally (2 out of 50 examined) are in contact with the xylem. The eggs are usually deposited with the long axis parallel to the grain of the wood. After deposition the female partially closes the incision with finely shredded bark fibers so that it is hardly discernible.

The egg is chalky white, opaque and elongate oval. Measurements of 10 eggs averaged 2.3 millimeters for greatest length and 0.7 millimeter for greatest width. The largest number of apparently mature eggs found in dissected females was 14, coincident with many rudimentary ones. Individual females oviposit for a week or more, and additional eggs are matured during this time.

The larvae through their boring activities ultimately score both the inner bark and the outer wood. Their frass-laden tunnels are narrow at first but widen as the larvae grow, and mature galleries often attain a length of 14 inches. Usually, however, the galleries are so tortuous and interlaced that individual ones cannot be readily traced. After larval development is completed, a cell is excavated either in the bark or in the sapwood, sometimes deep in the latter, wherein the pupal transformations take place.

The average duration of the prepupal period for 16 individuals kept in salve boxes in the outdoor insectary during May was about 5 days (minimum 1, maximum 13), whereas the average duration of the pupal period was about 20 days (minimum 13, maximum 25).

Strangely enough, detailed data as to the length of the life cycle of this abundant insect have never been published, but field observations and mass rearings of infested materials by many writers suggest that it requires at least 1 year, and possibly 2 or 3, for completion. Logs in which oviposition took place during June and July of 1935 were placed in screened cages and overwintered outdoors. The following spring and summer they were kept in emergence cages in the insectary, water being added to them occasionally

to simulate natural conditions. They were placed in outdoor screened cages for the second winter and then returned to insectary emergence cages in the spring of 1937. All the logs were debarked in October of 1937. Under these conditions certain individuals were able to complete their life cycle in 1 year, others required 2 years, while two larvae, had they lived, might have required 3 years (table 1). Late in March, 1936, at East Stroudsburg, Pa., several elm trees were cut which later became infested with *Saperda tridentata*. Sections of these trees were placed in emergence cages late in August of the same year. One hundred thirty-seven adults emerged during May and June of 1937 and 37 during the same months of 1938, indicating that under more nearly natural conditions the life cycle usually requires 1 or 2 years for completion and, contrary to the findings shown in table 1, that the greatest issuance occurs during the first year.

Table 1.—Duration of the life cycle of *Saperda tridentata*.

Date Mated Females Were Isolated, 1935	Number of Adult Progeny, 1936	Emergence Dates of Adult Progeny, 1936	Number of Adult Progeny, 1937	Emergence Dates of Adult Progeny, 1937
June 4	0	—	27*	June 1 to August 2
June 6	16	May 25 to June 15	0	—
June 7	1	May 23	1	June 15
June 14	1	May 25	1	June 1
June 26	2	June 27 to July 7	3†	June 15
July 2	7	May 27 to July 7	14	June 3 to June 15
July 15	0	—	10	May 24 to May 29
August 3	0	—	27	May 24 to June 15

* One live larva, which might have completed its development in 1938 had it not been disturbed, was found in October, 1937.
† One medium sized larva, which had recently died, was found in October, 1937.

The following species are probably most commonly associated with *Saperda tridentata* in New Jersey and neighboring states: *Magdalis armicollis* Say, *M. barbita* Say, *Neoclytus acuminatus* (F.), *Xylotrechus colonus* (F.), *Chrysobothris femorata* (Oliv.), *Scolytus multistriatus* (Marsham) and *Hylurgopinus rufipes* (Eich.).

The abundance of *Saperda tridentata*, as well as of its associates, can be materially reduced by the removal and burning of infested elm materials in the fall or winter, or before the adults emerge in the spring.

Magdalis armicollis.—Larvae of this species often occur in immense numbers under the bark of dying or recently dead elms and occasionally extend their galleries into the adjacent living tissue. In New Jersey, small suppressed trees with one or more dead branches in the crown appear especially vulnerable to this species. Galleries with small larvae were observed in the trunk of one apparently healthy, though suppressed, elm tree 3 inches in diameter breast high.

In New Jersey, adults begin to emerge through small holes in the bark of infested trees late in May. They continue to issue throughout the summer, and adults have been collected in the field as late as September. Laboratory rearings, based on approximately 1,300 specimens issuing from infested wood taken in different localities, indicated greatest emergence during May and June under outdoor conditions. On the other hand, when beetles were collected on felled trees at six localities, adults were most abundant during the summer, about 58 per cent of a total of 1,680 beetles being collected in July. Adults feed on the intervenal tissue of elm leaves, usually skeletonizing and often consuming entire portions of them. Such feeding has frequently been observed in parts of the crowns of standing elm trees, but it is rather inconspicuous and probably of little economic importance.

The mating habits of *Magdalis armicollis* were easily observed in the laboratory, where 17 pairs remained in coitu for an average of 25 minutes (minimum 5, maximum 58). Shortly after mating, the females began oviposition activities. Out of a total of 1,097 reared individuals 51 per cent were females. Under outdoor conditions adult progeny from a single female ranged from a few individuals to as many as 90.

Prior to the deposition of eggs the female makes a number of test punctures, which appear as small circular openings in the bark. If abundant, these are noticeable upon close examination. The female may then spend nearly an hour chewing out one of these punctures into a suitable receptacle. It takes her about 5 minutes to deposit a single egg or several eggs in the selected puncture, which usually terminates deep in the inner bark. She then ordinarily seals the cavity with fine brown borings and a secretion in such a manner that it is camouflaged.

Recently deposited eggs are elliptical, about 0.6 by 0.36 millimeter, and from white to light yellow in color. Indoors the length of the egg stage is about 9 days.

The larval tunnels usually radiate from a group of oviposition punctures often made about a knot or at the base of a twig. On the basis of 31 measurements, the average length of the galleries was about 44 millimeters (minimum 22, maximum 62). These galleries, generally speaking, are convoluted, run parallel with the grain of the wood, and score both the inner bark and the wood. A few observations indicated that the larvae of *Magdalis armicollis* molt four times before entering hibernation.

The larval tunnels gradually increase in size as the grubs develop, eventually terminating in a cell wherein the prepupal and pupal stages are passed. These stages required approximately 2 and 9 days, respectively, for a few individuals kept indoors. Hubbard (1874), on the other hand, found that the pupal stage was of 18 days duration at Cambridge, Mass.

Experiments similar to those described for *Saperda tridentata* were undertaken to determine the length of the life cycle of this species. As shown in table 2, it was invariably completed in approximately 1 year. Moreover, elm wood infested with this species collected in the fall and winter for rearing produced adults that always completed their emergence the following spring and summer.

Table 2.—Duration of the life cycle of *Magdalis armicollis*.

Dates Beetles Were Isolated, 1935	Number of Adult Progeny, 1936	Emergence Dates of Adult Progeny, 1936
May 11	3*	May 23 and June 8
May 14	5*	May 23 to June 15
June 6	32*	May 18 to June 20
June 6 to June 15	24	May 20 to June 8
June 26	90*	May 18 to July 7
June 18 to June 30	346	May 20 to June 27
June 20 to June 30	178	May 19 to July 7
July 3 to July 31	172	May 19 to June 15
August 3 to August 10	107	May 19 to July 14
August 10 to August 19	127	May 19 to July 21
August 19 to September 28	60	May 19 to July 7

* Progeny of one female.

This species often breeds in the same type of elm material as *Saperda tridentata* and its associates; control measures are therefore the same as for *S. tridentata*.—3-20-39.

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A Control for the Larvae of Houseflies in Manure Piles*

R. W. FAY, *Illinois Natural History Survey* and *Agricultural Experiment Station, Urbana*

The fecundity of the housefly, *Musca domestica* L., and the shortness of its life cycle are some of the factors which cause this species to be so abundant during the summer and early autumn months. In the study reported here, performed on the University of Illinois farm at Urbana, it was found that the adult female ordinarily deposits two to seven clusters of from 100 to 150 eggs each, preferably in the fresh droppings of horses and cattle.

* The work reported in this paper was undertaken during the summers of 1937 and 1938 under the direction of Professor W. P. Flint of the Illinois Natural History Survey and Agricultural Experiment Station, Urbana. Funds were provided by the University of Illinois. The author wishes to thank the members of the University faculty and the employees of the University farm for their cooperation.

These eggs usually hatch in 24 hours; the maggots undergo two molts, having three instars within 8 days when conditions are favorable. The pupae require from 4 to 7 days to develop, and the adults emerge, mate and oviposit after the second day. Thus the entire life cycle can be completed in 15 to 18 days.

Sprays and poisons for the control of adult flies are usually ineffective, as they often are applied after the adults have had an opportunity for oviposition. Effective control measures must be those which affect the immature stages.

ENVIRONMENTAL FACTORS.—In this study it was found that the adult flies lay eggs from one-half to 1 inch below the surface of manure, which must be less than 2 weeks old. Many eggs ordinarily have been deposited before the manure is removed from the barns, and therefore subsequent handling of the manure is important.

During development the maggots remain close to the point of oviposition and require quite specific environmental conditions for complete development. Hewitt (1909) stated that larvae under laboratory conditions could not live at temperatures as high as 104 degrees F., but he failed to mention the moisture content of the medium. The author of the present study found under field conditions that 120 degrees F. was lethal, although maggots were able to develop at temperatures as high as 110 to 116 degrees F. if the medium was moist. Field droppings of animals dry out rapidly when exposed to the sun's rays, and housefly maggots are unable to complete their development in these droppings except in rainy seasons. On the University of Illinois farm, the droppings of cattle and horses alone seemed to be attractive to the adult flies for oviposition.

With the requirements of the larvae in mind, the author examined the physical properties of manure when it was stacked in the field. The process of decomposition is exothermic, and temperature ranges of 140 to 170 degrees F. are attained in the interior of manure piles during the summer. These high temperatures are maintained through the interior of the piles and to within 8 inches of the surface, but at shallower levels the temperature falls rapidly to approach that of the surrounding air. Over a period of weeks the temperature approximately 4 inches below the surface of the manure ranges from 112 to 118 degrees F., regardless of fluctuations in the air temperature. The larvae therefore are forced to live in the outer 4 inches of the manure, and any measure which can reduce this space should decrease the number of larvae which can survive.

Hutchison (1914) noted that the full grown larvae of the housefly migrate to a dry medium for pupation. He took advantage of this instinct in working out a control for the housefly. He recommended daily watering of the manure and storing it in "maggot traps," containers surrounded by water to catch the migrating larvae.

HANDLING OF MANURE.—At the University of Illinois dairy barns during this study, the manure removed from the barns was segregated roughly into two types: (1) a light manure consisting mainly of soiled bedding material and (2) a heavy manure of almost pure droppings with very little bedding material. The manure was carried by conveyors out of the barns and dumped on the ground. This manure was then picked up daily by wagons and piled into ricks on a designated area of the farm. The two types of manure were piled separately, as the heavy manure decomposed more rapidly than the slightly soiled bedding material and was therefore ready sooner for use as fertilizer.

The ricks were approximately 250 feet long, 16 feet wide and 9 feet high. The sides of the ricks were made as nearly perpendicular as possible to facilitate the run-off of water in rainy weather and thus prevent the formation of depressions in the top and on the sides of the pile. These depressions enlarge the external surface of the pile and allow more room for maggots to develop. The manure was stacked 3 feet deep over the entire basal area of the rick and allowed partially to decompose before being covered by fresh manure. In the ricks composed of light manure very few maggots were found; so the method of forming the pile was not important. In the heavy manure ricks, however, a very large number of maggots was present. Since a period of 3 weeks often elapsed before more manure was added to the rick, these maggots were able to complete their growth, pupate and

emerge as adults unhindered. Random counts gave an average of 250 larvae per square foot of top surface in the two heavy manure ricks, and it was estimated that one-half million flies per week were emerging.

CONTROL.—Instead of covering the entire basal area of the rick to a depth of 3 feet before adding more manure to the top of the pile, workmen formed the rick by piling the manure to the final height of 9 feet over only a small area. Much of the fresh manure containing eggs and larvae was thus covered, and the temperatures due to decomposition became lethal. Unhatched eggs were destroyed and many young larvae unable to escape were killed. Further measures were then taken to render the top 5 inches of the manure unfit for larval development.

Cook *et al.* (1915, 1916, 1919) studied the control of housefly larvae in horse manure, but confined their work to chemical control. For treatment of 8 bushels of manure they recommend the use of 10 gallons of water containing either 0.62 pound of borax or 0.5 pound of hellebore. Borax sprays must be applied with care, however, as borax in high concentrations prevents plant growth and renders the manure unfit for use as fertilizer. The cost of hellebore makes treatment with it impractical for large amounts of manure. Mellor (1919) suggested creosote oil used at the rate of 4 gallons per ton of manure. In the use of this chemical, the manure must be sprayed in layers as it is piled; the time required for this treatment makes it impractical. Copeman (1916) suggested packing the manure as it was made into piles and using the heat of decomposition for control of the larvae. Manure treated in this manner is hard to handle when it is later used for fertilizing. A practical method of treating manure to control the housefly was therefore devised.

Standard 60-pound roofing paper was cut into strips 16 feet long and 3 feet wide. These strips were laid over the top surface of a fresh portion of the rick so that each strip lapped 3 inches over the one next to it. They were then held in place by bricks. This simple covering served two purposes: It acted as an insulator against loss of the heat of decomposition, and it absorbed heat from the sun, thus raising the temperature of the upper 4 inches of manure. Temperature readings were taken four times a day for 3 weeks. Just under the cover, the temperature averaged 40 degrees F. above that of the surrounding air. All stages of the housefly found in the manure were killed by a temperature of 120 degrees F. Therefore, when the air temperature exceeded 80 degrees F. for a period of 5 hours all larvae in the covered area of the rick were killed.

When the tar paper was removed, the larvae were found extended and stiff on the surface of the manure. These larvae underwent rapid decomposition when left exposed to the air. Pupae found in the covered area were taken into the laboratory, but no adult flies emerged. An uncovered control area 2 feet away from the covered area was teeming with larvae.

The tar paper apparently changed the condition of the manure, possibly by altering its moisture content. The cover was removed after 4 days, but no further oviposition of houseflies occurred in the manure, and larvae placed by the author in the rick failed to develop.

Although the tar paper was readily available, manipulation of the individual strips was time consuming. As an alternative procedure, a double paper-covered burlap sheet 20 feet square was impregnated with creosote oil and placed over manure. This sheet, held in place by stakes, covered the entire width of a rick and extended 2 feet down the sides. The sheet was thrown back when more manure was to be added, and then placed over the fresh manure. The entire operation of removing and replacing the cover required about 10 minutes. When the area under the cover had been built to a desired height, the cover was left in place for 5 days and then moved to a new pile. This covering, however, killed only about 90 per cent of the housefly larvae and pupae.

Some maggots near the edge of the area covered by the burlap were able to migrate from under the cover and pupate in the ground close to the sides of the rick. To trap these maggots, a ditch 6 inches wide and 6 inches deep was dug as close to the sides of the rick as possible. Within 12 hours this ditch filled with liquids seeping from the manure and trapped those larvae which escaped from under the cover. One day after the cover had been placed, the liquid in the ditch

beside the covered area of the rick was found to contain a layer one-half inch deep of drowned larvae. The ditch beside uncovered portions contained only a few scattered larvae. The covered and open portions of the rick were of the same age and composition. Observations indicated that most larvae pupated just under the surface of the uncovered portions of the manure and did not leave the pile.

This control is practical, as the cost of materials is low, the time required for the necessary operations is short and no technical knowledge is required to carry it out.

Field observations on treated and control plots gave clearcut results at all times. The decrease of adult flies in the area was marked. It was estimated that the numbers of flies at the dairy barns decreased 50 per cent.

SUMMARY.—A method for the control of housefly larvae in manure piles has been devised. This involves piling manure into ricks with sides as nearly perpendicular as possible and constructing a ditch along the sides of the rick. The upper surface of the manure is covered with tar paper or burlap impregnated with creosote. If the air temperature is as high as 80 degrees F. for a period of 5 hours during the time the cover is in place, all larvae in the manure will be killed. The cover may be removed at the end of 5 days and no further infestation by houseflies will occur.—3-28-39.

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Further Studies of Methyl Bromide as an Insect Fumigant*

HAROLD H. SHEPARD and ALBERT W. BUZICKY,† *University of Minnesota, St. Paul*

The use of methyl bromide as an insect fumigant has made rather remarkable growth the past year in the control of stored food insects, in the fumigation of green vegetables destined for points outside quarantined areas and in other more or less specialized fields. Canadian investigators (Phillips, Munro & Allen 1938) have found that methyl bromide fumigation is practical in the destruction of insects in harvested apples, although under certain conditions the treatment results in both external and internal injury to the fruit. Considerable success has been obtained in the use of methyl bromide for the control of cheese mites (Dustan 1938), the control of stored product insects (Piper & Davidson 1938) and the control of the vectors of sylvatic plague (Stewart & Mackie 1938). The gas was approved officially, February 15, 1939, for the treatment of nursery stock to be moved out of those areas quarantined by the United States Government because of the Japanese beetle.

In order to keep abreast of this growing interest in methyl bromide, laboratory tests were continued following those reported by Fisk & Shepard (1938). Most of the work consisted of determining susceptibilities of common species of stored product and household insects. Considerable attention was paid to the effectiveness of methyl bromide in relation to that of other fumigants in use at the present time. Unfortunately the time involved in arranging and calibrating an entirely different type of apparatus for handling

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† Dow Chemical Company Fellow.

Table 1.—Relative toxicity of fumigants to different species of insects at 25 degrees C. and a 5-hour exposure.

SPECIES, COMMON NAME AND STAGE	FUMIGANT	NUMBER USED	MEDIAN LETHAL CONCENTRATION (Milligrams/Liter)
Attagenus piceus (Oliv.) Black carpet beetle (larva)	Methyl bromide	839	17.5
	Chloropicrin	600	5.0
	Ethylene oxide	640	17.0
	Carbon disulfide	640	88.0
	Ethylene dichloride	580	195.0
Attagenus piceus (Oliv.) Black carpet beetle (adult)	Methyl bromide	350	9.5
	Chloropicrin	170	1.3
Tenebrio obscurus F. Dark mealworm (larva)	Methyl bromide	92	13.0
Tribolium confusum Duv. Confused flour beetle (adult)	Methyl bromide	—	10.2*
Oryzaephilus surinamensis (L.) Saw-toothed grain beetle (adult)	Methyl bromide	2,821	8.0
	Ethylene oxide	1,125	7.5
Tineola bisselliella (Hum.) Webbing clothes moth (larva)	Methyl bromide	56	7.0
Stegobium paniceum (L.) Drug store weevil (adult)	Methyl bromide	1,479	6.5
Acanthoscelides obtectus (Say) Common bean beetle (adult)	Methyl bromide	—	6.1*
Sitophilus granarius (L.) Granary weevil (adult)	Methyl bromide	—	5.5*
Rhizopertha dominica (F.) Lesser grain borer (adult)	Methyl bromide	2,443	5.4
	Chloropicrin	1,891	0.75
	Carbon disulfide	1,301	20.0
Zabrotes subfasciatus (Boh.) Mexican bean weevil (adult ♂)	Methyl bromide	490	4.2
Zabrotes subfasciatus (Boh.) Mexican bean weevil (adult ♀)	Methyl bromide	716	4.7
	Carbon disulfide	854	20.0
Sitophilus oryzae (L.) Rice weevil (adult)	Methyl bromide	—	4.0*
Plodia interpunctella (Hbn.) Indian-meal moth (larva)	Methyl bromide	180	5.0
	Chloropicrin	98	2.25
Plodia interpunctella (Hbn.) Indian-meal moth (adult)	Methyl bromide	188	3.1

* Figure previously published and inserted for comparative purposes.

hydrogen cyanide has prevented further comparison with that most important general purpose fumigant.

TOXICITY TO DIFFERENT SPECIES.—Mortality curves have been completed showing the toxic effect of methyl bromide on a variety of common insect pests. The methods used have been described by Fisk & Shepard (1938). From the mortality curves were estimated the median lethal concentrations in table 1. New data obtained for other fumigants have been included. In a few cases figures previously published have been inserted for comparative purposes and indicated by an asterisk (*). The arrangement of species is from the most to the least resistant, in so far as such an arrangement is possible.

In the time available for these experi-

ments it was not possible always to standardize size and age of the test insects as much as is desirable. A serious effort was made to obtain material from the laboratory cultures as nearly uniform as possible and in good health. The larvae of *Attagenus* were nearly full grown, mostly between 8 and 10 months from the egg. *Attagenus* adults, when they are 15 to 20 days old, exhibit increased susceptibility to fumigants; so the published figures are based only on those individuals 2 to 7 days old. The *Tenebrio* larvae were large size, nearly full grown. Those of the webbing clothes moth were probably about two-thirds grown. The larvae of *Plodia* were taken in the active crawling stage just before the cocoons are spun; the adults of this species were relatively young as they were taken from the cultures as fast as they emerged in enough numbers to use. The remaining adult insects were selected for normal activity, although those of *Stegobium* would have given better results if age distinctions had been made as in the case of the *Attagenus* adults.

The period of observation between the treatment and the final recording of mortality results varied with the species. Adult insects were observed for 48 hours only. The larvae required longer times, 3 days for *Tenebrio*, 4 days for *Tineola* and *Attagenus* and 5 days for *Plodia*. Longer observations were made but did not appear to alter the results very much. During the period of observation it is necessary to feed most of the species, especially if they are to be kept for an extended period. This is in contrast to *Tribolium* which is unaffected by being 2 days without food. Both adults and larvae of *Attagenus* were transferred from the fumigation cages to a mixture of corn meal and fish meal. The clothes moth larvae were placed on flannel and fish meal. *Oryzaephilus* adults and *Plodia* adults and larvae were fed the moist Haydak (1936) mixture. The *Tenebrio* larvae were placed in a mixture of dry cereals including rolled oats. *Rhizopertha* adults were given cracked wheat slightly moistened, and *Zabrotes* adults were similarly supplied with cracked beans. In order to reduce to a reasonable minimum of 1 to 3 per cent the check kills due to moisture loss it was necessary to place test lots of *Oryzaephilus*, *Stegobium*, *Rhizopertha* and *Zabrotes* in a moist chamber with the lid slightly open during the recovery period.

The larvae of *Attagenus* are conspicuously resistant to most of the fumigants tested. They are the hardest to kill with methyl bromide of all the insects tested. *Tenebrio* larvae are second in this respect. Larvae of *Tenebrio molitor* L. as well as those of *T. obscurus* were tested, but only 41 larvae were available. However, the results indicate this species has about the same resistance as *T. obscurus* to methyl bromide. The two sexes of adult *Zabrotes* are very dissimilar and easily separated. The male weighs 1.7 milligrams, the average of 145 individuals, whereas the female weighs 2.2 milligrams as determined from 325 individuals. It was of some interest, when the toxicity of methyl bromide was tested against the two sexes separately, to find the smaller male slightly but significantly more susceptible than the female.

Jones (1938) determined the relative toxicity of methyl bromide, ethylene oxide and methyl formate to *Tribolium castaneum* (Hbst.) at 27 degrees C. and a 5-hour exposure. The median lethal concentration of methyl bromide was 6.1 milligrams per liter, indicating that, as in the case of other fumigants, *T. castaneum* is more easily killed by methyl bromide than is *T. confusum*.

DELAYED MORTALITY.—Differences in the speed of action of insect fumigants were mentioned briefly by Shepard *et al.* (1937, p. 5) and Fisk & Shepard (1938). Although final observations of mortality have been made rather uniformly on the second day after the tests, that is, after a period of 40 to 48 hours, those insects showing any movement visible to the naked eye have been counted as alive on the chance that they might revive. For this reason the mortality figures reported in terms of dosage were believed to be on the safe side in being high rather than low.

During the present investigation, test lots of *Tribolium confusum* Duv. adults, exposed to a variety of fumigants, were set aside for daily records of mortality. Typical results are shown in fig. 1. It will be noted that the general trend over a period of several days is toward higher mortality, sometimes continuing for most of the 10-day period of the tests. Hydrocyanic acid is the exception in that those individuals that appear dead at the end of

a 5-hour exposure do not revive, and there is no delayed effect on the individuals that show life. Insects, then, react to cyanide in a manner very similar to mammals.

and fig. 2. As in the case of chloropicrin, carbon disulfide and ethylene dichloride, the dose of methyl bromide required to kill *Tribolium* increases only down to a

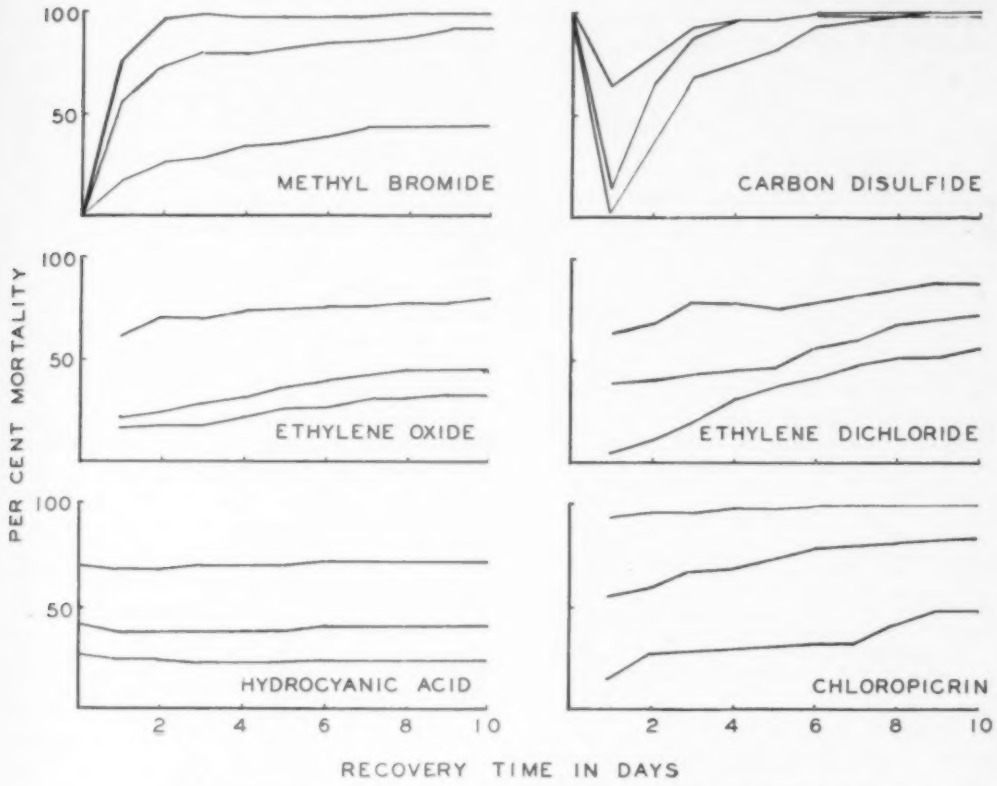

FIG. 1.—Apparent mortality of *Tribolium confusum* for several fumigants over a 10-day period after fumigation.

Carbon disulfide and methyl bromide produce quite different effects on *Tribolium*. Insects coming out of the former are anesthetized but revive by the end of a few hours, after which time the lethal effects of the gas become increasingly apparent over a period of several days. Insects coming out of methyl bromide, on the other hand, are not anesthetized but may appear to be quite healthy, yet all be dead at the end of 48 hours.

TEMPERATURE.—At the time of the previous report on the toxicity of methyl bromide as an insect fumigant the data for the lower temperatures (10 degrees to 0 degrees C.) were incomplete. Since then the values missing from the published table have been determined and some slight corrections made in the others. The completed data are presented in table 2

certain point, about 8 degrees to 9 degrees C. (about 45 degrees to 48 degrees

Table 2.—Relation of the toxicity of methyl bromide to temperature as expressed by the median lethal concentrations for 5-hour exposures.

TEMPERATURE		MEDIAN LETHAL CONCENTRATIONS IN MILLIGRAMS PER LITER	
Degrees C.	Degrees F.	*Tribolium confusum*	*Sitophilus granarius*
35	95	6.7	3.8
30	86	7.9	4.8
25	77	10.2	5.5
20	68	14.2	6.5
15	59	18.0	7.5
10	50	33.0	14.5
5	41	32.0	46.0
0	32	25.0	70.9

F.); then it decreases, apparently because of the added lethal effect of the low temperature. It is known that the average life of adult *Tribolium confusum* at 7 degrees C. is only 14 days (Nagel & Shepard 1934). The dose of methyl bromide required to kill *Sitophilus granarius* adults, however, continues to increase, at least

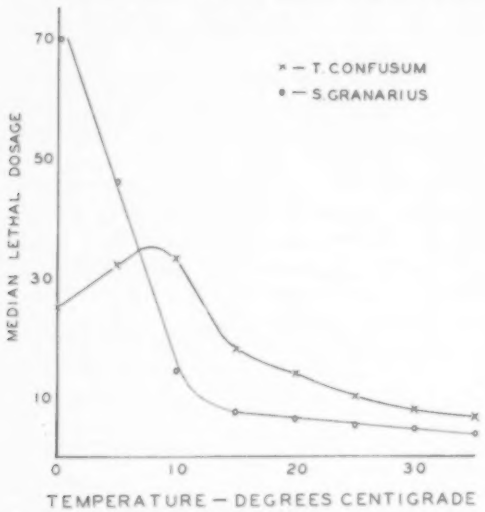

FIG. 2.—Median lethal dosages of methyl bromide, at various temperatures, for *Tribolium confusum* Duv. and *Sitophilus granarius* (L.)

to nearly 0 degrees C. Published figures for the mortality of the granary weevil at low temperatures without a fumigant show this species to be somewhat more resistant to cold than is *Tribolium*. The figures are not directly comparable to those for *Tribolium* but they indicate that a temperature about 0 degrees C. would be necessary in order to kill *S. granarius* as soon as *T. confusum* is killed at 7 degrees C.

ABSORPTION.—In addition to the work relative to absorption of fumigants in flour during 1937, experiments were conducted in 1938 to determine possible variations in the flour absorption ratio at different temperatures. When it was found that the absorption ratio of 2, previously reported for a temperature of 25 degrees C., also holds roughly for 30 degrees and 35 degrees, the lower temperatures were not investigated. The flour absorption ratio, described in the previous report, is the ratio of the median lethal concentration in equilibrium with a standard amount of flour to that in the empty flask. It can be used to indicate the relative absorption of a certain fumigant under varying conditions or of different fumigants under standard conditions.

Both flour and insects were prepared ready for fumigating and preheated at the desired temperature for 1 hour before the fumigant was introduced to the flasks. At 35 degrees C. the median lethal concentration for *Tribolium confusum* in an empty flask is 6.7 milligrams per liter, whereas that in a flask containing the standard amount of flour is 12.8 milligrams per liter. The absorption ratio previously determined for 25 degrees C. was 2.06; that for 35 degrees C. calculated from the above determinations is 1.91. Both figures are well within the limits of variation for such rough tests of absorption.

Preliminary attempts by manometric methods were made to determine in terms of gas pressure the rate of absorption of a fumigant in flour. The results indicate that this method may be productive of valuable information as to the fate of a gas in the presence of absorptive material. The lower boiling liquid fumigants have the steeper curves at the outset, indicative of rapid evaporation. When absorption becomes greater than evaporation or the latter is complete, the curve is reversed and then flattens out as the system comes to equilibrium. The rate and the degree of absorption combine to form a general picture of the specific gas absorption for each fumigant. Further work must be done, however, before dependable data can be published.

EFFECT ON BAKING QUALITIES OF FLOUR.—Samples of wheat flour, supplied by a Minneapolis milling company, were exposed to methyl bromide, the samples then being subjected to baking tests at the laboratories of the company. Four liters of flour, equivalent to about 2,100 grams (4.6 pounds), were placed in a 6-liter Erlenmeyer flask and exposed for 5 hours to a concentration of 32 milligrams per liter (2.0 pounds per 1,000 cubic feet). This dosage is based on the whole volume of the flask including both the space occupied by the flour and that above the flour. The tests were made in triplicate. The 5-hour exposure in glass is considered to be roughly equivalent to a 24-hour exposure in the average fumigatable structure. The baking tests, made

within a few days after the flour was fumigated, showed no detectable difference between check loaves and loaves made from the treated flour.

In this connection it is interesting to note the results of tests by Martin (1938) of the diastatic activity of ground wheat samples that had been fumigated with all the common insect fumigants, including methyl bromide. In no case did as much as five times the recommended dosage of fumigant injure the saccharifying amylase present in the wheat.

SUMMARY.—The toxicity of methyl bromide to a considerable list of stored product insects was determined, along with comparable new data for older insect fumigants. The larvae of the black carpet beetle, *Attagenus piceus* (Oliv.), were the most resistant to methyl bromide of the insects tested.

Differences in the speed of toxic action of fumigants were tested. Hydrocyanic acid exhibited no delayed action, all exposed insects being either dead or alive and active at the end of the exposure period. Insects exposed to carbon disulfide were anesthetized and exhibited partial recovery before many individuals succumb. Those exposed to methyl bromide at higher concentrations than necessary to kill 100 per cent seemed normally active immediately after exposure.

Data relative to the influence of low temperature upon the toxicity of methyl bromide were completed. The added lethal effect of the low temperature appeared to be a function of the cold resistance of the particular insect species concerned. Temperature appeared to have no effect upon the flour absorption ratio.

Baking tests with flour fumigated with methyl bromide at 2 pounds per 1,000 cubic feet showed no detectable injury.—3-29-39.

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Flight Habits of the Raisin Moth and Other Insects as Indicated by the Use of a Rotary Net

DWIGHT F. BARNES, CHARLES K. FISHER and GEORGE H. KALOOSTIAN, *U. S. Department of Agriculture, Bureau of Entomology* and *Plant Quarantine*

In studying the flight habits of insects affecting dried fruits, the authors used a rotary net lent during 1937 by the Modesto, Calif., laboratory of the Bureau of Entomology and Plant Quarantine, U. S. Department of Agriculture. This net was originally developed during the summer of 1935 by F. R. Lawson and J. C. Chamberlin for use in studies on the migration of the beet leafhopper, *Eutettix tenellus* (Bak.). It is an excellent apparatus for the study of insect flight movements because it samples the entire population in the air at the elevation at which it is operated. For some purposes a rotary net is preferable to light traps or bait traps, which capture chiefly the insects attracted to them. This net was very simi-

lar in principle to nets that were developed in England at about the same time by Williams & Milne (1935) and by Davis (1935).

The net, fig. 1, consisted of a rigid wire-cloth cone 53 inches long attached to a counterbalanced boom 12 feet long. The cone opening at the large end was about 19 inches in diameter and 2 square feet in cross section. Attached to the small end of the cone, which was 3 inches in diameter, was a removable cloth bag to receive the insects. A removable wire frame inserted in the bag kept it expanded and reduced whipping and shattering of the insect contents. The net was elevated about 3 feet above the ground. It was driven by a one-half horsepower electric motor and revolved horizontally in a 12-foot circle about once a second. The speed of the net was therefore 37.7 feet per second, 25.7 miles per hour or 616.8 miles per day. Since the machine was operated more than 130 days during the season, the net traveled more than 80,000 miles. The volume of air strained each day was about 6,514,000 cubic feet.

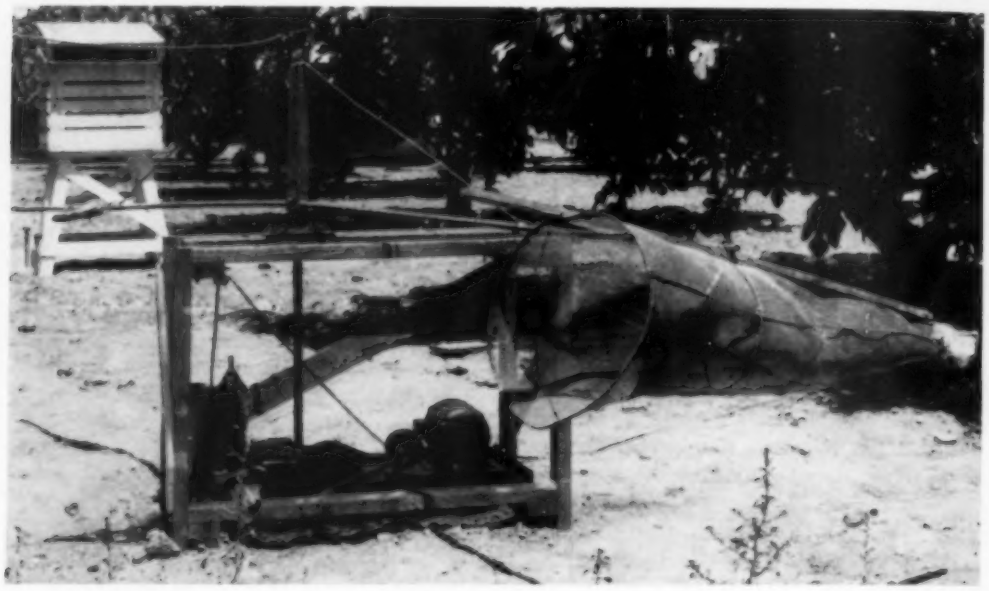

FIG. 1.—Rotary net in a fig orchard.

PROCEDURE.—The net was operated in a Mission fig orchard at Round Mountain, about 20 miles northeast of Fresno, to study the movement and abundance of the dried fruit beetle, *Carpophilus hemipterus* (L.). The spring and summer population proved to be small, and not many beetles were taken. Large numbers of other insects were captured, however, particularly adults of the raisin moth, *Ephestia figulilella* Greg.

The apparatus was placed in the orchard on June 16 and was run continuously until November 13, with the exception of 13 days when mechanical difficulties or interference by unauthorized persons interrupted the work. Each morning, except during the periods of interruption and on October 24 and 30, when the net was not emptied, the contents of the bag were brought to the laboratory for sorting.

Soon after the net was first used, it was noted that a considerable number of small moths was taken each day. No identifications were made until July 12, when 753 of these moths were counted in the catch. A sample of 103 was examined and found to contain 94, or 91 per cent, raisin moths. This indicated that 685 raisin moths had been taken during the 24-hour period, or, to be more exact, during the night of July 11–12. From then until the end of the season daily records of the number of raisin moths were kept. The last moths were taken November 6, but the trap was operated 7 days longer to make sure the end of the flight season had been reached.

Table 1.—Raisin moths caught in rotary net during the night of July 22–23, Round Mountain, Fresno County, Calif. 1937.

PERIOD ENDED*	TEMPERATURE, DEGREES F.	RELATIVE HUMIDITY, PER CENT	LIGHT INTENSITY, FOOT-CANDLES	MALES	FEMALES	PERCENTAGE OF FEMALES
P.M.						
7:15	86	33	5.0	0	0	0
7:30	85	33	0.50	0	0	0
7:45	85	34	0.25	0	0	0
8:00	84	35	0.25	2	3	60
8:15	84	32	0.0	5	2	29
8:30	82	39	0.0	3	7	70
8:45	82	36	0.0	1	14	93
9:00	82	36	0.0	0	10	100
9:15	82	36	0.0	4	14	78
9:30	82	33	0.0	0	5	100
9:45	81	36	0.0	0	9	100
10:00	80	41	0.0	0	5	100
10:15	80	38	0.0	1	8	89
10:30	79	40	0.0	0	2	100
10:45	79	40	0.0	0	7	100
11:00	79	43	0.0	1	1	50
11:15	79	40	0.0	0	2	100
11:30	79	40	0.0	2	0	0
11:45	78	39	0.0	0	1	100
12:00	76	44	0.0	0	1	100
12:15	75	47	0.0	1	1	50
12:30	75	47	0.0	0	4	100
12:45	74	47	0.0	0	0	0
A.M.						
1:00	75	47	0.0	1	1	50
1:15	75	51	0.0	3	0	0
1:30	74	47	0.0	2	2	50
1:45	74	47	0.0	4	0	0
2:00	74	50	0.0	0	0	0
2:15	73	53	0.0	2	2	50
2:30	71	52	0.0	4	2	33
2:45	71	52	0.0	1	0	0
3:00	70	51	0.0	4	1	20
4:00†	69	55	—	18	3	14
4:15	69	55	0.25	2	3	60
4:30	69	55	0.25	0	0	0
4:45	69	59	1.30	1	0	0
5:00	69	63	8.0	0	0	0
Total and average				62	110	64

* Sunset at 7:15 p.m. and sunrise at 4:57 a.m.
† No collections between 3 and 4 a.m.

In addition to the daily totals, flight records were made at 15-minute intervals throughout the whole flight period, or a part of it, for six nights, July 20–21, 22–23, September 7–8, 14–15, 17–18 and 23–24. These records included the number of moths taken, the temperature, the relative humidity and the light value in foot-candles as shown by a photoelectric exposure meter. A hygrothermograph was operated in an instrument shelter near the net from July 19 to the end of the season.

CATCHES OF THE RAISIN MOTH.—Between July 12 and November 6, 17,433 small moths were taken. The group consisted of moths about the size of the raisin moth; moths larger or smaller than the raisin moth were not included in the records. Since dissection of the genitalia was necessary for identification of the raisin moth, substantial samples were examined when a large number of moths were taken, and all were examined when the number was 100 or less. During the season 7,918 moths (45 per cent of the total) were examined. On the basis of this sampling it was estimated that 12,639 raisin moths were caught in 105 days, an average of 120 a day. This represents the number that attempted to cross a circle 12 feet in diameter at an elevation of about 3 feet.

Examination of the moths for determination of sex brought out the unexpected indication that the percentages of females in the daily catches declined as the season advanced. Grouped by months, the percentages were as follows: July, 54; August, 43; September, 39; October, 27; November, 21. The percentages of females that contained eggs, obtained from examinations begun in September, were as follows: September, 35; October, 27; November, 18. Although the proportions of females and of gravid females to the total moths in the air at the elvation of the net may have differed from the proportions in the population as a whole, the declining percentages probably reflected a general condition.

Flight records taken at 15-minute intervals during the night of July 22–23 are given in table 1.

On the six nights of short-interval observation the average time when flight began was 35 minutes after sundown. No close association between temperature or relative humidity and the beginning of flight was found. Light was a definite factor influencing the beginning of flight. On five of the six nights flight began when the exposure meter reading was 0.25 foot-candle or less. Casual examination of the figures for each period during the six nights showed a greater activity in the first 2 hours of flight than later. Flight continued throughout the night when the temperature was above 56 degrees F. Soon after flight began, the moths became very active and the number captured increased sharply. In the first hour and a quarter of flight the percentages of the total raisin moths taken during each of the six nights were 24, 27, 50, 24, 26 and 48. The percentages recorded in the early hours were larger on cool nights than on warm nights. This increase was due to a shorter flight period and a smaller total catch on cool nights, as the numbers of moths taken did not differ greatly. The numbers of moths recorded in the first hour and a quarter were 52, 47, 43, 54, 57 and 41, and numbers for the whole flight period were 213, 172, 86, 225, 215 and 86. The third and sixth nights in this group were cool.

Female moths started flight as soon as conditions were favorable and flew actively for about 2 hours, after which their activity decreased. On cool nights the flight of the females was 75 per cent over by the end of this period and on warm nights it was 60 per cent complete. Not only was the percentage of the total females high early in the night, but the percentage of those carrying eggs was greater than it was later. From 60 to 80 per cent of the egg-bearing females were taken during the first hour of flight and from 86 to 94 per cent by the end of the second hour.

The flight of the males followed a different time-distribution pattern from that of the females. On warm nights, when flight could be maintained all night, males flew in moderate numbers for an hour and were relatively quiet for several hours, followed by a period of activity between 2 and 4 a.m. All flight ceased shortly before sunrise. On the night of July 22–23, 18 per cent of the males taken were recorded during the first hour of flight and 47 per cent between 2 and 4 a.m.

Table 2.—*Cnemeplatia sericea* beetles caught at 15-minute intervals after sunset on six nights.

Light Intensity, Foot-Candles	Number of Beetles	Percentage of Total Catch
160.0	0	0.0
65.0	0	0.0
40.0	5	0.4
20.0	0	0.0
10.0	1	0.1
8.0	0	0.0
5.0	4	0.3
3.2	2	0.2
2.5	0	0.0
1.0	37	3.3
0.5	775	69.3
0.25	292	26.1
0.0	3	0.3

CATCHES OF CNEMEPLATIA SERICEA HORN.—This small beetle, of the family Tenebrionidae, was recorded because it had been observed feeding on fallen figs and because its activity was delicately controlled by light intensity. Table 2 combines the collections taken after sunset on six nights. There appears to have been no close correlation between temperature or relative humidity and the numbers taken. Flight usually continued for only 30 to 45 minutes and within a very restricted range of light values. The different light intensities and the numbers taken at each were associated. Of 1,119 beetles captured, 95 per cent were taken when the light intensity was 0.5 to 0.25 foot-can-

dle, 0.3 per cent when it was zero and 3.3 per cent when it was 1.

OTHER INSECTS RECORDED.—Only 1,386 dried fruit beetles were taken in 136 trap days. August was the month of greatest abundance. The beetles did not fly at night.

During the warmer part of the summer large numbers of several species of small staphylinid beetles were taken. Like *Cnemeplatia sericea*, these insects flew when the light was decreasing, but they were less sensitive to control by light intensity.

Between June 30 and July 19, 880 honeybees, or more than 48 per day, were taken in the net. They appeared in the catches soon after first-crop figs became abundant on the ground, rose to the greatest numbers on July 11 and 12 when figs on the ground were most plentiful and were no longer taken after this crop was harvested.

SUMMARY AND CONCLUSIONS.—A motor-driven rotary net operated in a fig orchard near Fresno, Calif., captured 12,600 raisin moths from July 12 to November 6, 1937. Comparative abundance from day to day was shown by daily collections from the net bag, and data were obtained on the percentages of gravid females.

The flight habits of the raisin moth, *Ephestia figulilella* Greg., and of *Cnemeplatia sericea* Horn were studied in detail by making collections at intervals of 15 minutes on six nights. The raisin moth began to fly about 35 minutes after sunset; females were the most active early in the evening. Flight was controlled by light intensity. *C. sericea* exhibited a restricted flight period of about 45 minutes, just before darkness set in. Counts were made of dried fruit beetles, *Carpophilus hemipterus* (L.), staphylinid beetles and honeybees that were taken in the collections.

Since the rotary net is nonselective, it offers a useful means for obtaining information about the aerial activity of both sexes of flying insects at any time of day or night.—4-3-39.

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Further Investigations on the Control of the Velvetbean Caterpillar, *Anticarsia gemmatilis* (Hbn.)

L. O. ELLISOR* and E. H. FLOYD, *Louisiana Agricultural Experiment Station, University*

The velvetbean caterpillar, *Anticarsia gemmatilis* (Hbn.), as previously, became a serious pest of soybeans in Louisiana in the fall of 1938. The first larvae of the season were taken on July 15 in south and central Louisiana, but they did not appear in destructive numbers until about August 15. It was not until caterpillars of the third generation appeared, however, about September 15, that extensive defoliation of soybeans resulted. An unusual feature of the outbreak in 1938 was the fact that the caterpillars appeared simultaneously in destructive numbers at localized points throughout the state. This species usually appears first in the southern part of the state and spreads northward as the season advances.

In this paper are presented data obtained from laboratory and field experiments with insecticides for the control of the velvetbean caterpillar. The experiments were conducted at the Louisiana State University and in the immediate vicinity during the late summer and fall of 1938.

MATERIALS.—Recently molted last instar larvae were used in the laboratory tests. They were collected from soybeans several hours before they were used.

The insecticides were fresh samples of proprietary products. The compositions of these are as follows:

Cryolite.—Three different brands of cryolite were used: *Alorco* cryolite, a neutral, domestic, synthetic cryolite containing 87.1 per cent sodium fluoaluminate; *Syncrolite*, an imported synthetic cryolite claimed by the manufacturers to

* Died October 21, 1939.

be 98 to 100 per cent pure; and *Dusting* cryolite, an experimental material of good dusting properties containing 31.7 per cent sodium fluoaluminate. *Alorco* and *Dusting* cryolite were prepared by the Aluminum Ore Company.

Barium Fluosilicate (*Dutox*).—The manufacturer, E. I. du Pont de Nemours Co., claims that this material contains 72 per cent barium fluosilicate and 8 per cent sodium fluoaluminate.

Magnesium Arsenate.—This material was made by the Dow Chemical Company. The following analysis appears on the container: not less than 48.80 per cent tri-magnesium arsenate; not less than 20.90 per cent metallic arsenic; not more than 0.23 per cent soluble metallic arsenic.

Basic Lead Arsenate.—This material was prepared by the Sherwin-Williams Company. The following analysis appears on the package: metallic arsenic, 14 per cent; total soluble metallic arsenic not less than 0.50 per cent.

Basic Copper Arsenate.—This material, prepared by the Sherwin-Williams Company, contains the following: 44.8 per cent copper and 40.6 per cent As_2O_5 to which was added 2 per cent zinc hydrate. The particles ranged from one to three microns in size and the water-soluble As_2O_5 value was 0.15 per cent when in equilibrium with CO_2 of the air.

Dual Fixed Nicotine.—This is a non-volatile nicotine compound composed of nicotine tannate and nicotine bentonite. It contains 3.75 per cent nicotine, and was prepared by the Tobacco By-Products and Chemical Corporation.

Derris Dust.—To ground derris root containing 4.1 per cent rotenone and 14.1 per cent total extractives (analyzed by Insecticide Division, Bureau of Entomology and Plant Quarantine, U. S. Department of Agriculture) was added talc as a carrier, and a wetting agent, *Vatsol OS* (sodium salt of an alkylated naphthalenesulfonate obtained from American Cyanamid and Chemical Corporation), so that the final admixture contained 1 per cent of rotenone and 1 per cent of wetting agent.

LABORATORY TESTS.—In order that fairly accurate comparisons of the toxicity of a number of insecticides could be made quickly, a gross feeding method was employed which permitted the application of near-equivalent quantities of given poisons to given leaf areas. The method of applying the insecticides to the leaves was suggested by Dr. Harold Waters of Ohio State University. It consisted principally of discharging a weighed amount of poison into a cylinder 10 inches in diameter and 48 inches in height, and allowing the poison to settle to the bottom on the foliage, which previously had been pinned flat to the floor of the container. The dusting apparatus consisted of a 10-cubic centimeter bulb type pipette with the top half of the bulb removed. Several abrupt turns were made in the lower or constricted portion of the pipette in order to break up lumps of the insecticide. The insecticide, after being placed in the bulb end, was shaken down into the constricted portion of the tube between the enlarged part and the first bend. The large end of the apparatus was closed with a rubber stopper through which passed a glass tube that connected with a $2\frac{1}{2}$-inch rubber bulb. The insecticide was blown directly upwards through the bottom center into the dust tower by a single blast of air. In the experiments reported in this paper, the insecticides were allowed to settle for 2 minutes on soybean foliage which had been moistened. When the insecticide was blown into the dust tower in the manner described, it settled very uniformly on the bottom, as was revealed before and after dusting by weighings of glass slides placed at different points on the bottom.

After a leaf was dusted, the stem was pushed through a hole in a cork stopper that was then fitted into a shell vial filled with water. The vial containing the leaf was then placed on moist packed sand at such an angle that the undusted surface of the leaf just touched the sand, thus permitting larvae which fell off to get back on the dusted leaf. Five caterpillars were used in each test, and after they were put on the dusted leaf a cage was placed over the whole to prevent the escape of the larvae. Checks were run with all tests. The number of larvae dead at the end of the first, second and third days was recorded.

RESULTS AND DISCUSSION.—The results of these laboratory tests are given in table 1. In early tests, 100 milligrams of insecticides were employed, but since *Alorco* cryolite, *Syncrolite*, *Dutox*, basic

lead arsenate and basic copper arsenate killed 100 per cent of the larvae in 72 hours, the amount applied was reduced to 50 milligrams in order that a comparison could be made between these materials. Of the fluorine insecticides used in these tests, it appeared that *Syncrolite* was slightly more toxic than any of the others; it killed 83 per cent of the larvae in 72 hours, whereas *Dutox* killed 65 per cent, *Alorco* killed 73 per cent and *Dusting* cryolite killed 31 per cent. The apparent greater toxicity of *Syncrolite* over about the toxicity to be expected when the fluorine content of this material is compared with that of *Alorco* cryolite or *Syncrolite*.

The caterpillars fed almost as readily on the foliage dusted with magnesium arsenate as they did on the checks. Very little mortality or symptoms of toxic action resulted, since most of the caterpillars pupated normally. Both basic lead and basic copper arsenates exhibited strong symptoms of toxic action, which were particularly noticeable by the fact

Table 1.—Toxicity of several insecticides to last instar velvetbean caterpillar larvae.

Insecticide	Number of Tests	Total Number Larvae	Per Cent Mortality		
			1 Day	2 Days	3 Days
Dutox	20	100	9	40	65
Alorco cryolite	20	100	32	61	73
Syncrolite	20	100	32	63	83
Dusting cryolite	20	100	2	18	31
Magnesium arsenate	20	100	1	5	6
Basic lead arsenate	20	100	6	34	64
Basic copper arsenate	20	100	54	77	90
Dual fixed nicotine	20	100	1	3	8
Derris dust, 1 per cent rotenone*	20	100	0	0	0
Check	20	100	0	0	1

* One hundred milligrams of dust applied; 50 milligrams used in all other tests.

Alorco cryolite is most likely due to the fact that it is composed of larger particles than *Alorco* and more of the poison settled out in 2 minutes with this material. At first the larvae fed readily on the foliage dusted with all three of the cryolite insecticides.

Dutox appeared to be slightly more distasteful to the larvae than any of the other fluorine insecticides employed; foliage dusted with it was not eaten readily. Its speed of toxic action proceeded slowly as compared with cryolite; for instance, at the end of 24 hours only 9 per cent of the larvae had died as compared with 32 per cent fed *Alorco* cryolite and *Syncrolite*. The mortality with *Dutox* had increased noticeably by the end of the second day and by the end of the third day had almost reached that of *Alorco* cryolite and *Syncrolite*.

In earlier tests with *Dusting* cryolite it appeared that this material had greater toxicity than would be supposed from its fluorine content. The results of these tests, however, do not show this to be the case, since only 37 per cent of the larvae were dead in 72 hours. This is that the caterpillars did very little feeding on foliage dusted with either of these materials. It is interesting to compare the percentage mortality with these two insecticides at the end of the first day; for instance, the mortality was 6 per cent among the larvae on the leaves dusted with basic lead arsenate as compared with 54 per cent on the leaves dusted with basic copper arsenate.

The leaves dusted with dual fixed nicotine were eaten as readily as were those in the undusted checks, and most of the caterpillars developed and pupated normally.

The 1 per cent derris dust exhibited no toxicity for this species.

FIELD EXPERIMENTS.—Tests were conducted with *Alorco* cryolite, *Syncrolite*, *Dutox* and basic copper arsenate in caterpillar infested fields of soybeans near Baton Rouge, La. Basic lead arsenate was highly toxic to larvae in laboratory tests, but it was not included in these field experiments, since it caused rather severe burning of soybean foliage.

All of the soybeans were planted in $3\frac{1}{2}$-foot rows. With the exception of that in

one field, the bean foliage completely covered the ground at the time the insecticides were applied. The insecticides were applied late in the afternoon with either a saddle gun or with a 5-row *Root* dusting machine. The first application was made when the caterpillars became sufficiently abundant to cause noticeable ragging of foliage, and again if the condition recurred.

In test number 1, the first application of insecticide was made on August 17, and the second application on September 1. In test number 2, the first application was made on August 31 and the second on September 9. Only one application of insecticide was needed in tests 3 and 4 and was applied on September 9 and 11, respectively.

RESULTS AND DISCUSSION.—Table 2 shows that good control of velvet-bean caterpillars was obtained with all of the insecticides used in these fields under the conditions in which the tests were run. In all cases the check plots were completely defoliated and no seed was produced. In tests 1 and 2, two applications of poison were made in order to obtain seasonal control. The beans in tests 3 and 4 escaped heavy infestation in August, and hence the first caterpillars to appear in destructive numbers in these beans were of the third generation, and only one application of insecticide was necessary to give seasonal control. With both samples of synthetic cryolite, good control was obtained in 48 hours after the insecticides were applied. The basic copper arsenate appeared to be a little more rapid in action, and the *Dutox* a little slower.

It was observed in test number 4 that basic copper arsenate was noticeable on the leaves for a long period after the insecticide was applied. In order to determine whether the residue was toxic to soybean caterpillars, 10 fifth instar larvae were placed on a sample of these leaves that were taken from the field 16 days after the poison was applied and after 1.13 inches of rain had fallen. After the caterpillars had been on the foliage for 3 days, five were dead, two were sick and very little of the foliage had been eaten. These results indicate that the residue was toxic. Larvae placed on samples of the leaves dusted with cryolite at the same time fed and pupated. On October 15, or about 5 weeks after the insecticides were applied in test 4, 100 sweeps with a net were made in each of the cryolite treated plots and in the copper arsenate treated plots. Forty-two, 43 and 3 larvae were taken in the plots treated with *Alorco*, *Syncrolite* and basic copper arsenate, respectively. The persistent visible residue on bean

Table 2.—Results from insecticides used as dusts in field tests on velvetbean caterpillars, 1938.

Test No.	Treatment	Variety of Beans	Size of Plot, Acres	First Application		Second Application		Yield Seed Beans, Pounds Per Acre
				Pounds Per Acre	Control	Pounds Per Acre	Control	
1	*Alorco*	Avoylles	4.0	7.0	Good	6.8	Good	1,482
	Alorco	Otootan	3.7	7.0	Good	7.5	Good	368
	Check	½ Avoylles ½ Otootan	2.0	—	90% defoliated		Defoliated	0
2	*Alorco*	Otootan	2.0	8.5	Good	10.0	Good	414
	Dutox	Otootan	2.5	8.4	Good	10.0	Good	483
	Check	Otootan	1.0	—	50% defoliated		Defoliated	0
3	*Alorco*	Palmetto	9.0	9.0	Good	Not needed		529
	Check	Palmetto	1.0	—	Defoliated	—		0
4	*Alorco*	Avoylles	0.5	10.0	Good	Not needed		736
	Syncrolite	Avoylles	0.5	10.0	Good	Not needed		526
	Basic copper arsenate	Avoylles	0.5	7.5	Good	Not needed		654
	Check	Otootan	0.5	—	Defoliated	—		0

foliage dusted with copper arsenate indicated that this material has excellent adhering properties, and the laboratory feeding test on residue-bearing foliage showed that the material retained a lethal degree of toxicity for at least 16 days after application.

SUMMARY.—The results of laboratory and field experiments with insecticides for the control of the velvetbean caterpillar, *Anticarsia gemmatilis* (Hbn.), are given.

As revealed by laboratory tests, *Dutox*, *Alorco* cryolite, *Syncrolite*, basic lead arsenate and basic copper arsenate are highly toxic to the caterpillars, but dual fixed nicotine, derris dust, magnesium arsenate and *Dusting* cryolite exhibit little or no toxicity.

Basic lead arsenate, injurious to soybean foliage, was not used in field tests.

In field tests, *Alorco* cryolite, *Dutox*, *Syncrolite* and basic copper arsenate gave good control of caterpillars without damaging soybean foliage.

Basic copper arsenate exhibited unusual sticking properties and retained its toxicity several weeks after application.—5-15-39.

Light Traps and Codling Moth Control

D. W. HAMILTON and L. F. STEINER, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine*

The study of light traps as a control measure for the codling moth, *Carpocapsa pomonella* (L.), began during the latter part of the nineteenth century, when the use of such traps was urged for the control of a number of important insect pests. As a result of careful studies of this possible control method, Slingerland (1902) reported that codling moths were not attracted to the kerosene-lantern type of trap. Interest in the possibilities of such means of control has been revived in recent years by Herms (1929), Headlee (1932), Collins (1934), Parrott & Collins (1934), Marshall & Hienton (1935) and others. Certain of these investigators have found that the codling moth becomes photopositive in the presence of electric lamps having a relatively high output of near ultraviolet radiation.

Late in the spring of 1934 the Bureau of Entomology and Plant Quarantine, U. S. Department of Agriculture, undertook a field study of light traps on a large scale to determine their value as a control measure for the codling moth and the relative efficiency of the light sources available for such traps. The light traps were so placed that their effectiveness could be compared with that of bait traps located in the same orchards. The study was carried on in southern Indiana during 1934 and 1935,* and certain supplementary experiments were made in the Hudson Valley, N. Y., in 1936. Although, largely because of the cost of installation and maintenance of the traps, the work did not lead to a practical control measure for the codling moth, it seems worth while to place on record a brief summary of the results obtained, together with certain observations made during the course of the work.

THE EXPERIMENTAL ORCHARDS.—The Indiana experiments were carried on in the Troth-Burton orchard, near Orleans. In 1933 more than 90 per cent of the apples produced in this orchard had been injured by the codling moth. Some indication of the insect population is given by the fact that more than 250,000 moths emerged within the packing shed during the spring of 1934.

The light-trap experiments were carried on in a 5¼-acre block of 30-year-old trees located near the center of the orchard. For several years this part of the orchard had been the most severely infested. The lighted block was 9 rows wide and 24 rows long in 1934 and was reduced to 8 rows in width in 1935. The rows extended east and west and were surrounded entirely by orchard except for a small pasture along the northeast boundary. Because of missing trees only 175 were available for use within the block. Three varieties, Jonathan, Rome Beauty and Winesap, were represented. The trees of each variety extended north and south across the area in double or quadruple rows.

* M. S. Troth, manager of the Troth-Burton orchards, gave valuable assistance throughout the investigation and furnished records on infestation for years prior to 1934; G. E. Marshall and T. E. Hienton of Purdue University supplied information on light sources based on studies carried on by them in 1933; and T. E. Hienton assisted in arranging the engineering details.

The presence of a large bait-trap area and of blocks of other varieties in the orchard limited the location of the trees used for check purposes to three blocks, one northwest, one southeast and the other immediately south of the test block.

Owing to the severity of the infestation no reduction in control practices by the grower was deemed advisable. Both check and trapped areas were therefore given a full control program, which included scraping and banding, and a heavy schedule of lead arsenate sprays. This program was followed in both 1934 and 1935.

FIG. 1.—The mercury vapor tube and trap with its basket and bird guard in place. All other types of traps used in the experiments were constructed without grid baffles.

At Poughkeepsie, N. Y., the light-trap area consisted of a block of mature trees four rows by six rows, located near the center of a Baldwin orchard. A similar block containing 30 bait traps was located nearby. The regular spray schedule, consisting of a calyx and a cover spray of lead arsenate, was followed by the grower. Because of the small size of this block and the light codling moth infestation, this experiment was used only for comparison of the efficiency of different lamps, and no measurement of the control obtained was attempted.

LIGHT TRAPS TESTED AND THEIR ARRANGEMENT.—All the light traps were of types commercially available. Each consisted of a lamp surrounded by an electrified grid and was equipped with a transformer and a wire basket having a cover of coarse hardware cloth. The transformer was used to give the proper voltage for the grid and in some cases for the lamp. The cover was necessary to protect the catch from birds. The lamps were turned on and off by an electric time clock. During the period of experimentation in 1934, the traps were operated most of the night, but only during the evening and early morning in 1935.

In 1934 three types of lamps were used, *G-1* mercury vapor clear glass, *CX* 60-watt inside frosted, and *Mazda* 60-watt clear. The traps were arranged in groups of four trees to each type. These groups were given a restricted randomization within the block and replicated at least 14 times.

In 1935 the *CX* 60-watt frosted lamp was discontinued and the following were added: *Mazda* 150-watt clear, *Mazda* 300-watt clear, *CX* 250-watt inside frosted and a mercury vapor tube consisting of 8 feet of 9-millimeter tubing arranged in a coil. In the traps lighted with the tube, electrified baffles extended from the regular grid in four directions, fig. 1. The west three-quarters of the light-trap area was divided into six blocks of four six-tree rows, each block containing two of the three varieties of trees present. The *G-1* mercury vapor lamp was used in three of the blocks and the *Mazda* 60-watt clear in the other three. The east quarter of the area was used to test traps placed in single trees in a Latin square arrangement. The traps contained six types of lamps.

In 1936 the light traps were randomized in single trees. Each type was replicated six times.

The types of lamps used each year are shown in table 1.

PLACING OF TRAPS IN TREES.—At Orleans one trap was suspended in the top of each tree and over each of 15 vacant spaces in the outer rows. The traps were arranged so that they could be pulled up to a messenger cable and out

FIG. 2.—Light traps in apple trees, arranged so that they could be pulled up and out over the "middles" and then lowered for examination.

over the tree "middles" and then lowered to the ground for inspection, fig. 2. The messenger cable extended the length of each long row and was supported at 8-rod intervals by 30-foot poles. It served as one of the two lines carrying current to the traps, the hot line being located above it.

At Poughkeepsie the traps were hung directly in the trees and lowered to the ground by means of a pulley. Wires supplying the current were strung through the trees and attached to them by porcelain knobs. Such an installation, although simpler and cheaper than that used at Orleans, does not permit the traps to be placed so high or so effectively in the trees.

RECORDS OF MOTH CAPTURES.—The average moth catches made by the various types of lamps at both Orleans and Poughkeepsie are given in table 1.

Although the catches were small in 1935 and 1936, the mercury vapor tube

Table 1.—Average numbers of codling moths captured by various light traps in experiments at Orleans, Ind., and Poughkeepsie, N. Y.

	NUMBER OF MOTHS CAUGHT PER TRAP				
	Orleans			Poughkeepsie	
	Groups of Trees				
TYPE OF LAMP	1934	1935	Single Trees 1935	June 1–17 1936	July–August 1936
Mercury vapor tube	—	—	11.2	5.2	18.5
G-1 mercury vapor	178.2	13.1	11.0	2.3	17.0
CX 250-watt frosted	—	—	10.5	6.5	11.5
Mazda 300-watt clear	—	—	8.3	—	—
Mazda 200-watt clear	—	—	—	—	8.3
Mazda 150-watt clear	—	—	6.5	—	—
Spotlight 250-watt clear	—	—	—	1.8	—
CX 60-watt frosted	96.7	—	—	—	—
Mazda 60-watt clear	82.0	5.4	3.5	—	—
Least significant difference at odds of 19 to 1			4.1	3.4	7.6

and the *G-1* mercury vapor lamp appeared to be about equally attractive and definitely superior to the *Mazda* lamps of 200 watts or less.

The average catches of 8.3, 6.5 and 3.5 moths, respectively, for the 300-, 150-, and 60-watt *Mazda* lamps in the 1935 Latin square test indicate that attractiveness is proportional to light intensity, other things being equal. Since the *G-1* lamp is of lower wattage than any of the *Mazdas* used, one might conclude that quality of the light is more important than intensity. The results suggest that adjacent to lighted trees captured only about 5 moths each. It appears therefore that lights attract moths little more than one tree-row away, or about 35 feet. Since the intensity of light varies inversely with the square of the distance from the source, it is apparent that the intensity of light from even the most attractive lamp would be tremendously diminished one tree-row away.

CONTROL RECORDS.—At Orleans, records of worm injury were made in the lighted area and in the three check areas. Trees selected for infestation records were

Table 2.—Codling moth infestations in area containing light traps and in unlighted area, Orleans, Ind., 1934–1935.

YEAR AND VARIETY	LIGHTED AREA				UNLIGHTED AREA*			
	Number of Trees	Number of Apples Per Tree, in Hundreds	Number of Worm Holes Per 100 Apples	Total Injuries Per 100 Apples†	Number of Trees	Number of Apples Per Tree, in Hundreds	Number of Worm Holes Per 100 Apples	Total Injuries Per 100 Apples†
1934								
Jonathan	7	37.3	22.1	—	26	22.4	50.0	—
Rome Beauty	10	40.2	14.8	—	9	45.5	17.2	—
Winesap	10	40.1	5.2	—	29	30.2	8.0	—
Average		39.2	14.0	—		32.7	25.1	—
1935								
Jonathan	34	28.1	0.1	0.3	41	31.0	1.6	3.7
Rome Beauty	49	21.5	0.3	0.8	16	32.1	2.8	7.5
Winesap	64	39.9	0.1	0.4	44	33.7	0.4	3.1
Average		29.8	0.2	0.5		32.3	1.6	4.8

* Averages of the infestations in the three check blocks.
† Worm holes plus stings.

the *Mazda* 300-watt and the *CX* 250-watt lamps approach the *G-1* in attractiveness because the near ultraviolet rays emitted by them are close to the intensity of those given off by the *G-1* lamp.

Since the *CX* 250-watt and the *Mazda* 300-watt lamps consume more current, and the *G-1* lamp seldom lasts more than one season and gradually loses efficiency, it appears that the mercury vapor tube might prove the most practical.

From table 1 it will be noted that in 1935 the *G-1* and *Mazda* 60-watt lamps showed about the same relative attractiveness in solid blocks of 24 trees and in single trees adjacent to other types of lamps. In the 1934 tests the 175 traps suspended over trees averaged approximately 127 moths per trap, whereas the 15 traps suspended over vacant spaces distributed uniformly over the check and lighted areas.

In 1934, because of the heavy infestation, only the worm holes were recorded. In 1935 weather conditions were extremely unfavorable for the codling moth, and owing to the light infestation both worm holes and stings were counted. Adequate samples, usually of 200 to 500 apples, were taken at random from each drop pick-up and harvest picking. The samples were examined and the infestation for each tree was calculated on the basis of injuries found in the samples and the total number of apples represented by the samples. Table 2 shows the infestation in both lighted and unlighted areas at Orleans in 1934 and 1935.

Although the data for 1934 show a reduction of 44 per cent in worm holes

per 100 apples, the actual reduction is believed to have been greater than this figure because the lighted area was known to have been more severely infested the preceding year than the unlighted area. In 1935 the reduction in infestation, as indicated by total injuries per 100 apples, was 90 per cent.

TIME OF MOTH CAPTURE IN BAIT AND LIGHT TRAPS.—Examinations of certain traps were made at half-hour intervals on several different days each season to determine the periods of greatest moth activity. Unlike bait traps, the lights do not begin to attract moths in the evening until almost complete darkness has set in. Very few moths were caught when the light intensity exceeded 0.2 foot-candle. Although moths were captured at all hours from late dusk to early dawn, 85 per cent entered the traps before 10:30. Peak captures occurred between 7:30 and 9:30, depending on the time of sunset and degree of cloudiness. It should be stated that, whereas bait traps capture moths during periods of normal flight activity at dusk and dawn, light traps artificially stimulate activity after it normally ceases in the evening or before it begins at dawn. Thus, light-trap catches may be better indicators of moth abundance than bait traps, but less informative as regards the amount of normal activity that occurs. No captures were made during periods of rainfall, but activity often occurred after the rain ceased.

MOVEMENT AND RECOVERY OF MARKED MOTHS.—During 1934 and 1935, 655 newly emerged moths were marked and released in the light-trap area in lots of 100 to 150. Recoveries ranged from 17 to 43 per cent. Since rains occurring during the time these moths were in the orchard may have removed the dye, some of the marked moths may have been recovered without being identified as such. Thirty-two per cent of all moths released during the two reasons were recovered. Moths traveled an average distance of 75 feet before being caught. The longest distance any moth traveled before recovery was 1,089 feet. Some moths were recovered as late as 11 days after being released, but the most moths were recovered during the first and second nights after release. Some of the moths released in the light-trap area were recovered in bait traps, whereas others released in the bait area were captured in the light traps. Moths released in the check area were captured in both the light and the bait traps, an indication that the nearest check areas were being drained of a part of their codling moth population by the traps.

CAPTURES IN MARGINS OF THE LIGHTED AREA.—Light traps located in the outer two rows captured more moths per trap than did those located in the interior of the block. Between 71 and 75 per cent of the total captures occurred in the outer traps. In 1934, traps in border rows averaged 167.1 moths per trap as compared to 71.3 in the interior of the area. In 1935, traps in border rows averaged 13.3 moths per trap as compared to 5.4 in the interior. Since it appears that the moths are not attracted very great distances to the lights, the larger proportion of captures in border traps is probably due to their more favorable position for capturing moths entering the area in the course of normal flight.

EFFECT OF POSITION OF LIGHT TRAPS.—The position of the trap in the tree in relation to foliage is very important. In the *G-1* series, traps 18 inches above the foliage captured an average of 46 moths each, those within 18 inches of the foliage 66 moths, those with the basket lowered into the foliage 81 moths and those with all the trap lowered into the foliage 136 moths. The best location appears to be as high in the tree as possible with only a small amount of foliage near and above the top of the trap.

LIGHT-TRAP VERSUS BAIT-TRAP CAPTURES.—The presence of the large bait-trap area in another part of the same orchard at Orleans made possible a comparison of moth captures by the two types of traps.

In 1934, moth captures in the $5\frac{1}{4}$-acre light-trap area averaged 4,038 moths per acre and 126.9 moths per trap, 44 per cent being females. The 35-acre baited area captured an average of 26.4 moths per trap, 66 per cent being females. In 1935, the infestation was so low in the lighted block that an average of only 9.5 moths per trap were captured, 35 per cent being females. Bait traps in an adjacent 24-acre block averaged 6.3 moths per trap, 55 per cent being females. Because of its smaller size the light-trap area undoubtedly was subject to a greater reinfestation from the

surrounding check area than was the baited block, which may account in part for the greater catch per trap.

In 1936 at Poughkeepsie the block of 24 light traps averaged 18.1 moths after June 1, whereas the adjacent block of 30 bait traps averaged 16.1 moths per trap during the same period. Females constituted 36 and 52 per cent of the total captures made in the two areas.

SUMMARY.—A field experiment for studying light traps as a control measure for the codling moth and for determining the relative efficiency of the light sources available for such traps was begun in 1934. The presence of bait-trap areas in the same orchards made comparisons between the effectiveness of bait traps and light traps also possible. These investigations were conducted on a relatively large scale at Orleans, Ind., during 1934 and 1935, and continued on a small scale at Poughkeepsie, N. Y., during 1936.

Comparative tests of the relative attractiveness of different types of lamps indicated that the mercury vapor tube and the *G-1* mercury vapor lamp are about equally attractive to codling moths and definitely superior to *Mazda* lamps of 200-watts or less.

The results showed that the lamps used were not powerful enough to attract moths much farther than 35 feet. Fifteen traps hung over open spaces averaged only 5 moths per trap as compared to 127 for those in adjacent trees.

In 1934 at Orleans codling moth infestation in the $5\frac{1}{4}$-acre area containing light traps was reduced 44 per cent below that in the surrounding check blocks. The area was normally one of the most seriously injured in the orchard. In 1935 seasonal conditions were extremely unfavorable for the codling moth, and the lighted area showed a reduction of 90 per cent in infestation.

Because they artificially stimulate activity during hours when the natural light is too weak for normal activity, light traps are good indicators of moth abundance, but are less informative than bait traps as to normal flight activity. Whereas light traps captured more moths per trap than nearby bait traps, the percentage of females was much smaller.

Releases of marked moths indicated that moths left the light-trap area as well as entered, and some apparently remained within the area as long as 11 days before capture. The most recoveries were made the first or second night after release.—4-18-39.

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The Comparative Value of Honeybees in the Pollination of Cultivated Blueberries

F. R. SHAW, J. S. BAILEY and A. I. BOURNE, *Massachusetts State College, Amherst*

Previous to these studies there was some question as to the value of the honeybee, *Apis mellifera* L., as a pollinator of cultivated blueberries. Some workers have suggested that since the honeybee, because of its short tongue, could not collect nectar from the blueberry flower it would not attempt to work that plant. Others have mentioned the bumblebee as being of importance but say nothing of the comparative importance of the different species involved. The value of solitary bees likewise has not been studied, or at least no reports were available.

In order to obtain information on the

pollination of cultivated blueberries a study of the insects concerned with their pollination was begun in 1936. These experiments were made in an attempt to answer the following questions.

1. Can honeybees pollinate cultivated blueberries successfully?
2. What groups of insects are most concerned with pollination under natural conditions.

All of the observations were made in the plots of cultivated blueberries at the Massachusetts State College, Amherst.

Table 1.—Number of fruits on branches of blueberry bushes exposed to bees and protected from bees, 1936.

Varieties	Number of Fruits on Branches	
	Exposed to Bees	Protected From Bees
Harding	42	0
Pioneer	16	0
Grover	36	0
Pioneer	32	3

TESTS MADE.—In order to determine the effectiveness of the honeybee as a pollinator the following tests were made.

To exclude insects, two cheesecloth tents were set in place; each tent covered two varieties of cultivated blueberry bushes. A nucleus hive, consisting of three frames of sealed brood and bees and one frame of honey, was placed in each tent. Provision was made for the bees to obtain water. The bees were left in the tents during the blooming period and then removed.

At the time of harvesting the crop, the number of fruits was obtained from branches which had been covered to exclude all insects with the possible exception of small ants. This yield was compared with that obtained from branches of similar size exposed to bees. Table 1 summarizes the data thus obtained.

From these data it is evident that bees can pollinate cultivated blueberries.

During 1936 preliminary studies were made to determine the groups of insects most important in blueberry pollination. It was possible to take only a limited number of counts. However, the honeybee was found to be the most numerous single species visiting blossoms, bumblebees (two species) were next in abundance and the solitary bees ranked third. It was decided to continue these observations in order to determine the relative abundance of honeybees, bumblebees and solitary bees present, and to determine the number of visits made to blueberry blossoms per minute by insects of these groups.

In 1937 these investigations were continued. Counts were made of the number of visits per minute per individual of 10 honeybees and 10 bumblebees in each experiment. The data thus obtained are presented in table 2.

From these data it is evident that the bumblebee was about three times as efficient per individual as the honeybee in the pollination of cultivated blueberries.

In 1938 the following experiments were conducted.

Tents were placed over pairs of bushes of four varieties of cultivated blueberries

Table 2.—Number of visits per minute per individual of 10 honeybees and 10 bumblebees in each of the 1937 experiments.

Date and Hour of Observation	Temperature, Degrees F.	Number of Visits Per Minute Per Individual					
		Maximum		Minimum		Average	
		Honeybees	Bumblebees	Honeybees	Bumblebees	Honeybees	Bumblebees
May 21 3:00–3:45	65	6	20	4	12	5.0	14.9
May 23 1:30–2:10	83	8	24	4	15	5.6	19.5
May 24 2:00–2:40	74	7	23	4	12	5.3	17.4
May 25 2:50–3:30	75	7	22	4	13	5.6	18.5

to compare the set obtained on bushes pollinated by honeybees with that on bushes exposed to open pollination and on bushes screened to exclude all insects. The results of these experiments are presented in table 3.

Table 3.—Percentage of set of blueberries, 1938 experiments.

Variety	Honeybees Alone	No Insects*	Open Pollination
Cabot	94.0	1.5	75.8
Pioneer	80.7	1.7	68.8
Pioneer	94.8	0.6	
Jersey	94.9	0.7	77.4
Pioneer	87.9	0.0	
Rubel	93.8	0.9	89.4

* These figures are based on the number of clusters inclosed in cheesecloth bags and an estimate of the number of blossoms per cluster.

Through the assistance of two students, Beckman and Tannenbaum, counts of the insects visiting cultivated blueberries were obtained over a period of 2 weeks. A total of 1,170 insects was taken. Of these 37.8 per cent were honeybees, 46 per cent were bumblebees, 7 per cent solitary bees and 6 per cent Diptera. The number of remaining insects was insignificant.

SUMMARY.—As a result of experiments conducted for 3 years at Massachusetts State College, the following information was obtained concerning the pollination of cultivated blueberries.

1. Honeybees are effective as pollinators of cultivated blueberries.

2. Under the conditions of the experiments the bumblebees were the most important insects pollinating cultivated blueberries. Honeybees were second in importance, solitary bees, third.

3. Under the conditions of the experiment bumblebees worked approximately three times as fast as did the honeybees. —5-11-39.

The Effect on Humans of the Ingestion of the Confused Flour Beetle*

H. B. MILLS and J. H. PEPPER, *Montana Agricultural Experiment Station, Bozeman*

During the past year, information has been requested from the Montana Agricultural Experiment Station concerning possible ill effects which might result from the ingestion of the confused flour beetles, *Tribolium confusum* Duv., accidentally included in cereals.

No information covering this point was found in the literature, and because certain legal actions involved this question, experiments were undertaken to discover what the effects of ingestion of these insects might be.

TEST WITH RATS.—Experiments were first conducted on rats. Twelve young rats, weighing approximately 40 grams, were divided into four groups on March 31. They were starved one day and, on April 1, three groups were fed 10 grams per individual of stock rat ration to which had been added 1 per cent by weight of crushed adult beetles. One lot contained raw adult beetles, another cooked adults and the third dead adults from a flour culture. The fourth was kept as the check and fed the same weight of stock rations without addition of beetles. On the days following, the food cups were kept full of insect-free stock ration. All four groups were weighed and examined daily. The percentages of original weight were computed and are presented in table 1.

Table 1.—Per cent of original weight of young rats fed 1 per cent by weight of adult confused flour beetles on April 1.

Date	Raw Adults	Cooked Adults	Desiccated Adults	Check
April 1	90.3	90.0	89.8	89.5
April 2	109.6	109.0	107.8	107.9
April 3	116.9	116.5	113.4	112.8
April 4	124.2	123.4	120.5	119.3
April 5	135.5	132.5	129.0	127.3

Nine adult rats were divided into three groups and in a manner fed similar to the others except that one group was fed a 1 per cent by weight ration of raw larvae and another 1 per cent by weight of boiled larvae. The third group was kept as the check. Daily weights and observations

* Contribution from the Montana State College, Agricultural Experiment Station, Paper No. 125, Journal Series.

Table 2.—Per cent of original weight of adult rats fed 1 per cent by weight of larval confused flour beetles on April 1 and 2.

DATE	RAW LARVAE FED APRIL 1	COOKED LARVAE FED APRIL 2	CHECK
April 1	91.1	91.4	92.9
April 2	94.0	101.9	92.7
April 3	101.2	105.4	98.0
April 4	103.3	106.0	105.4
April 5	104.7	107.2	106.8

were taken. The percentages of original weight are shown in table 2.

It will be seen from tables 1 and 2 that the inclusion of flour beetles at the rate used produced no effect on the weights of either the young or adult rats. Daily examinations did not reveal any digestive disturbance whatever. The numbers of insects used were far in excess of even a heavy population in cereals. From the above data it would not be expected that the ingestion of these insects by humans would produce any harmful effects.

TEST WITH HUMAN BEINGS.—On the basis of the information obtained from the rat tests, a trial was carried out on human beings. Four normal healthy individuals varying in age from 28 to 44 years volunteered for this experiment. Each individual ate 25 adult confused flour beetles, 25 larvae, a few pupae, cast skins, eggs and some excrement boiled in approximately 2 ounces of oatmeal. Two individuals had had but a cup of coffee previously on the morning of the trial, and 2 ate normal breakfasts. The infested oatmeal was eaten at 9 A.M. and no further food was taken until noon.

Detailed blood and urine analyses were made on the day previous, the day of the trial and on the 2 days following. Bowel habits and general health were noted throughout the course of the experiment. No deviations from the normal for each of the individuals, either in the analyses or in general condition, were noted.

Again the number of flour beetles ingested was far in excess of populations which would be encountered normally in infested cereals.

No evidence was gathered in the above experiments which would indicate that injury to human beings would result from the ingestion of confused flour beetles as they may accidentally occur in cooked cereals.—5-26-39.

The Possibility of Intestinal Myiasis in Man

WILLIAM A. RILEY, *University of Minnesota, St. Paul*

The important experimental studies on intestinal myiasis recently published by O. R. Causey (1938) raise once more the question as to whether intestinal infestations by dipterous larvae actually occur or whether the numerous recorded cases are explainable on the basis of stool contaminations.

CAUSEY'S EXPERIMENTS.—The experimenter fed dipterous larvae to cats and dogs, both young and old. The larvae tested were those of a pomace fly, *Drosophila melanogaster* Meig., the black blowfly, *Phormia regina* (Meig.), the greenbottle fly, *Lucilia sericata* Meig., the secondary screwworm fly, *Cochliomyia macellaria* (F.), the red-headed blowfly, *Calliphora erythrocephala* (Meig.), and a fleshfly, *Sarcophaga securifera* Vill. In the five cases in which the larvae were recovered in the feces they were dead and completely digested, except for the chitinous covering. In 11 other experiments the animals were autopsied within 3 hours after feeding and, in every instance except one, the larvae were found dead in the stomach. The exception was that of a dog which had been starved for 24 hours prior to feeding and after ingesting the larvae had been allowed to drink water. The animal was autopsied 1 hour after feeding and all of the larvae found immobile but not dead. In the case of two other dogs similarly handled but autopsied 5 hours later, the larvae were found dead in the intestine.

CAUSEY'S CONCLUSIONS.—From these experiments, Causey is led to discredit all records of the discharge of living larvae from the alimentary tract. One may grant that "it is difficult to understand how fly larvae can produce symptoms such as have been attributed to them." A similar statement could be made regarding helminth parasites of man and such expressions as "intestinal discomfort," "nausea," "pot-belly" and the like have been used with little dis-

crimination in the one instance as well as the other.

DISCUSSION.—It must be remembered, however, that a limited series of experiments may be wholly negative without justifying the disregard of many detailed reports by careful physicians and entomologists who have been well aware of chances of error involved. Similar negative results could be obtained by administering infective stages of cat ascarids to human beings. Children everywhere are exposed to innumerable opportunities to pick up infections of these worms and yet instances of their developing in man are so rare as to be veritable medical curiosities. In these rare instances some abnormal condition of the individual has made it possible for the worms to maintain themselves. The possibility of this occurring in the case of fly larvae would seem fully established and Causey himself leaves room for some such interpretation when he says, "Conditions must be favorable for the larvae to make a quick exit from the stomach if they are to cause any severe disturbance,—in the normal intestinal tract these conditions do not prevail."

The possibility of larvae surviving passage through the digestive tract, and being discharged alive in the feces, Causey dismisses with the statement that, "Any one familiar with the life history of the muscoid flies realizes, however, that the living larvae must represent contamination after passage." This statement is reminiscent of one made a few years ago by a distinguished parasitologist who, in his emphasis on the idea that insects were air-breathing and hence could not live in the intestine of an animal host, overlooked the fact that larvae of *Gasterophilus* normally live for many months in the stomach and duodenum of horses, that larvae of *Hypoderma* migrate for months in the tissue of cattle before they come to lie under the skin of the back (there are numbers of records of their migration in the body of man) and that various mites live under the skin and even in the peritoneal cavity of animals. These, and many other instances of the ability of air-breathing arthropods which normally live in similar locations might be given.

Of the hundreds of alleged cases of intestinal myiasis recorded, there are many which may fairly be questioned but many also which cannot lightly be dismissed. Of the latter, we may cite the very striking one reported by Herms & Gilbert (1933), a case briefly referred to by Causey. Over a considerable period of time when living larvae were being discharged, the patient was under close supervision by the physician. Moreover, the editor to whom the report was submitted took the precaution of writing to Gilbert to inquire as to the completeness with which extracorporal contamination had been excluded and received the reply that, "There was absolutely no chance of error in obtaining the specimens. They were obtained from defecation, from vomitus and from the rectum through a proctoscope."

Over a period of years, the present writer has seen his share of dubious cases of alleged intestinal myiasis—cases which could either be dismissed as clear instances of contamination or, at best, could not be established as valid instances of facultative parasitism. On the other hand, he has seen a number of cases in which it was certain that living dipterous larvae had been discharged from the human intestine. The majority of these related to *Sarcophaga*, two to *Fannia* and one to the rat-tailed maggot, *Eristalis*.

The statement that Patton & Evans (1929) "suggest that the larvae of some Diptera such as *Aphiochaeta*, *Fannia* and *Sarcophaga* can perhaps survive the action of the gastric juice and even reach maturity in the alimentary canal" is hardly correct. Patton is an outstanding authority in this field and in the text cited (pp. 460–1) he makes the statement that "The larvae of some Diptera, such as *Aphiochaeta*, *Fannia* and *Sarcophaga* are able to survive the action of the gastric juice and even reach maturity."—5-8-39.

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Analysis of the Water Extract of Derris and Cubé

L. D. Goodhue and H. L. Haller, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine*

The sap, or water extract, from fresh derris root was used as an insecticide by Chinese gardeners long before the value of derris was known to the western world. The crude, but nevertheless effective, method of preparation used by these gardeners was to mash the fresh root by beating and to extract the juices by squeezing. In this way a very large portion of the insecticidal constituents were removed in the form of a milky colloid similar to rubber latex. This material was applied fresh before it had time to ferment and cause coagulation. In South America the water extracts of cubé and other poisonous plants have long been used as fish poisons.

In parts of the world where only the dried root of derris or cubé is available, little attention has been given to water extracts. The preparation of these extracts from the dried root has been studied to some extent at the Kolonial Instituut Te Amsterdam (1929), where it has been found that about half the active ingredients can be removed in the form of a suspension if the root has been finely ground. Recently the Bureau of Entomology and Plant Quarantine, U. S. Department of Agriculture, has had several inquiries about the preparation and properties of water extracts for special uses such as in insect baits. The information gathered to answer these requests is presented here for the benefit of others who may find this method of application adaptable to their particular problem.

Extracts having about the same properties as those made from the fresh root can be prepared easily from finely ground (200-mesh) derris or cubé. The particles are so small and they are so well protected that only a small portion will settle in a month. By evaporation under reduced pressure more concentrated suspensions can be prepared than it is possible to hold in solution in most organic solvents. Furthermore, owing to the high degree of subdivision, this extract should have very high toxicity as either a contact or a stomach poison.

There is a relatively large loss of active ingredients in the marc when dried roots are used, but for special purposes this is a minor factor. In a commercial process successive extractions could be made with the consequent removal of quantities up to 75 per cent. The dried marc might find a use as a diluent, or it could be extracted further with some organic solvent.

The water extract contains many substances that are not active poisons. Some of them are very good dispersing agents and give a high degree of stability to the colloid. It is not definitely known what compounds are responsible for this stability, but among many complicated plant products glucosides similar to the saponins are known to be present. The presence of free and combined sugar is demonstrated in this paper. This partly accounts for the rapid fermentation when the extracts are not preserved. The finding of glucose and levulose in about equal proportions suggests the presence of sucrose, but none of these sugars has been isolated in crystalline form.

Materials.—A total of seven samples, including derris, cubé and timbo, were chosen for the preparation and study of the water extracts. Because there is considerable variation in roots available on the market, it seemed desirable to test as many samples as was practicable to be reasonably certain that a good water extract could be prepared from any that might be encountered. All the samples taken from lots of finely ground commercial roots. One sample, no. 2178, was taken from the fine material that collects in certain parts of the grinding apparatus. It was thought that the fine material could be more easily extracted, but actually no difference was noted.

Method of Extraction.—Fifty grams of each sample were shaken overnight with 250 cubic centimeters of water in a 500-cubic centimeter Erlenmeyer flask. A few drops of xylene were used as a preservative. The xylene reduced foaming without coagulating the suspension. In the morning the extract was squeezed with the hand through a silk bag made of 200-mesh bolting cloth. (A muslin bag could be used.) The marc was stirred up with 150 cubic centimeters of water,

which was again removed by squeezing. This rinsing operation was repeated, and the combined extract and washings were made up to a volume of 500 cubic centimeters. The marc, which had been freed of as much water as possible, was spread out on a paper to dry. This method of separating the marc from the extract is much better than filtration. Kneading with the hand greatly aids in removing the extract. The extract cannot be filtered through filter paper without removing much of the insecticidal material. At first it comes through practically unchanged, but as the pores of the paper become clogged only the clear liquid, minus the suspended resin, is allowed to pass.

These water suspensions are very well stabilized. The small amount of marc that passes through the silk bag quickly settles, but the milky suspension of resin shows practically no change in a month. The extracts range in color from cream to light brown. The lighter extracts are from derris. Toluene and xylene are fairly effective preservatives, but they might interfere with the use of the material as an insect bait. Formaldehyde (0.1 per cent) is recommended in this case.

CHEMICAL ANALYSES OF THE MARC AND EXTRACT.—The amount of rotenone in the air-dried marc was determined by the Jones (1938) method and the percentage calculated on the basis of the original weight of the root. The difference between this value and the total rotenone gave the amount in the water extract. The red color (Goodhue 1936) given by the marc compared with the original as 100 per cent was also determined. The red color and total solids were also determined on the extracts 3 hours after preparation and after standing 2 days. For determination of the red color, 5 cubic centimeters of the extract were diluted to 100 cubic centimeters with acetone, and after the greater part of the precipitated material had settled the analysis was made in the usual way. The small amount of water did not interfere. To determine total solids 5 cubic centimeters of the extract were evaporated and the residue weighed.

The red color method was chosen because it has been shown to be roughly correlated with the toxicity to houseflies (Jones, Campbell & Sullivan 1935). By this method it is easy to determine the proportion of toxic material removed without a complicated analysis. It will also be noted that in most cases the red color from the marc plus that of the extract totals about 100 per cent. This gives a fair check on the analysis. The percentage of rotenone extracted varies greatly with the sample. The average is well under 50 per cent. Since rotenone tends to crystallize after partial removal of the extract, it may not be removed easily.

Sample no. 3833 was extracted twice in the manner described above. Another

Table 1.—Chemical analyses of samples of derris, cubé and timbo, and of their water extracts and marcs. (All figures are per cents.)

MATERIAL AND SAMPLE	ORIGINAL SAMPLE		MARC		WATER EXTRACT				
					After Settling 3 Hours			After Settling 2 Days	
	Rotenone*	Total Chloroform Extract	Rotenone†	Red Color†	Red Color†	Rotenone†	Total Solids	Red Color†	Total Solids
Derris									
2178	7.1	23.4	58	81	25	42	2.54	25	2.36
3006	3.6	16.5	66	67	31	34	1.8	18	1.4
3007	0.6	13.6	83	60	28	17	1.63	22	1.2
3833	4.6	14.0	48	60	41	52	1.72	38	1.35
Cubé									
2711	1.8	9.2	33	66	26	67	2.07	21	1.74
3004	2.9	16.4	66	75	24	34	2.22	19	2.11
Timbo									
3230	3.9	19.2	64	70	27	36	2.43	20	1.92

* Except for no. 3833 these samples were taken from lots already analyzed by H. A. Jones, of the Division of Insecticide Investigations.

† These values indicate the percentage of the total amount appearing in the original root.

12.7 per cent of active ingredients was removed, as indicated by the red color test. Since most of the stabilizing and dispersing agents were removed in the first extraction, the second extract was much less stable. The chemical analyses are summarized in table 1.

MATERIALS SOLUBLE IN THE WATER PHASE.—For a study of the water-soluble material sample no. 3833 was used, and the extraction was made in a different manner. Chloroform was first used to remove all the resinous material before extracting with water. The water extract was prepared and filtered by suction through a bed of marc. The filtrate was a slightly turbid liquid, which showed some fluorescence in sunlight. After evaporation to one-fourth its volume, four volumes of methyl alcohol were added. This caused the precipitation of gums and many glucosides. Some of these materials had the foaming power of saponin, but none were hemolytic when tested with red blood cells.

The filtrate was further concentrated in vacuo. The sirup so obtained reduced Fehling's solution strongly upon being warmed. With 1 gram of the residue an osazone was easily prepared. The properties were those of glucosazone. To determine the total reducing power, 0.5 gram of sirup was hydrolyzed with dilute hydrochloric acid and made up to 100 cubic centimeters. A 15-cubic centimeter portion gave 0.0411 gram of cuprous oxide, indicating about 1 milligram per cubic centimeter when figured as glucose. A 30-cubic centimeter portion was oxidized with bromine for 3 days, after which it gave 0.0416 gram of cuprous oxide, indicating about 0.5 milligram per cubic centimeter of ketose figured as levulose. The solution was next tested with resorcinol and hydrochloric acid. A strong red color, showing the presence of levulose, was obtained. When carried out quantitatively as directed by Snell & Snell (1937), the solution was found to contain 0.52 milligram of levulose per cubic centimeter. A solution of glucose and levulose should be levorotatory, but in every case this material was weakly dextrorotatory. This is probably due to the presence of dextrorotatory gums or other soluble materials. The presence of about equal quantities of glucose and levulose suggests the presence of sucrose, but no crystalline sugars have been isolated. Since the sugars have no toxicity to insects, the investigation has not been carried further.

SUMMARY.—The water extracts of seven samples of derris, cubé and timbo have been examined chemically. From 24 to 41 per cent of the active material can be removed by one extraction, and successive extractions remove more. When preserved against fermentation, these suspensions of the active principle are very stable.

Both glucose and levulose were found to be present in one sample. The glucosides similar to saponin had no hemolytic power.—5-26-39.

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SCIENTIFIC NOTES

Injury to Sweet Corn by *Euxesta stigmatias* Loew in Southern Florida

Euxesta stigmatias Loew, apparently a native of the West Indies,* was first observed by the writer in Dade County, Fla., in February and March, 1936. At that time, as well as during a similar period in 1937 and 1938, the maggots were observed feeding in the internal silks of occasional ears of the sweet field corn varieties Snowflake and Tuxpan. Although the insects increased in abundance as the season advanced each year, and were most plentiful late in March, at no time did they cause injury to the ears beyond rotting of the silks or sometimes

* According to H. Loew (Berl. Ent. Zeitschr. 11: 311.1867) the type material was from Cuba and Brazil.

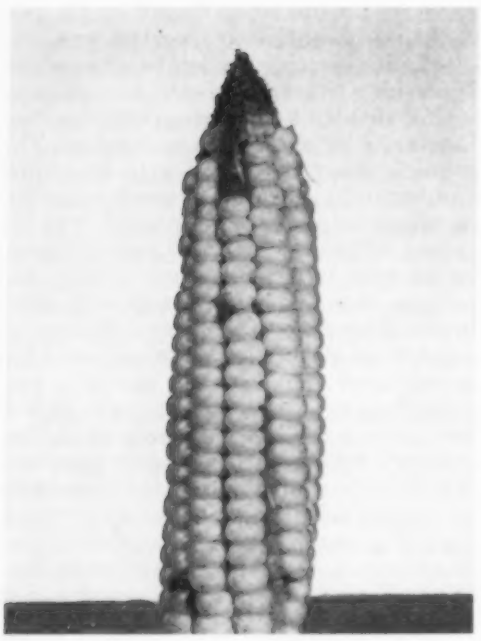

FIG. 1.—An ear of sweet corn in which *Euxesta stigmatias* maggots had fed on the silk and cob tip, causing rot.

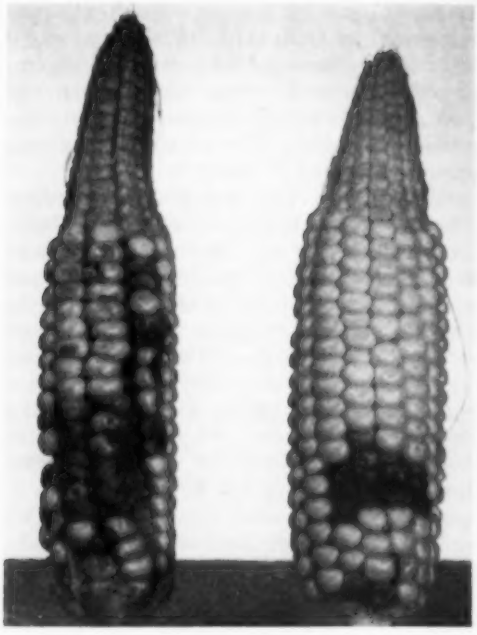

FIG. 2.—Ears of sweet corn in which *Euxesta stigmatias* maggots had fed on the kernels.

the extreme tips of cobs. Fig. 1 shows an ear of sweet corn in which the tip of the cob had rotted.

In 1939, plots of sweet corn of several varieties were grown at the East Glade Farm of the Florida Subtropical Experiment Station. This was one of the most southeasterly located cornfields in the state. An acreage of sweet corn on a private farm about 5 miles north of the East Glade Farm was also under observation.

Euxesta appeared in the sweet corn at the East Glade Farm about the first of March, and by the middle of that month approximately half the ears then being harvested in roasting-ear stage of growth were infested. In many instances maggots had penetrated to kernels on all parts of the ears. Such kernels became shrunken and browned as a result of feeding by the maggots. Fig. 2 shows ears injured in this way. In the acreage of sweet corn 5 miles north the insect was scarce at this time, only an occasional ear being infested.

The difference in type of injury to ears of field corn and ears of sweet corn seemed to be correlated with differences in the husk character of these two types of corn. The sweet field corn varieties Snowflake and Tuxpan are characterized by very tight husks, which lay so closely about the kernels that it is probable the maggots could not reach them. Ears of sweet corn are characterized by much looser husks, which allowed the maggots to penetrate to kernels on all parts of the ears. The population of maggots per ear was often from 10 to 20 but usually less.

The location of the serious infestation in the sweet corn at the East Glade Farm suggested that adults probably had been carried to this cornfield from the West Indies by wind, which usually blows from the east or southeast during February and March. Since an abundance of food was found at that location, the insect bred there continuously and had spread little by the end of March.—8-7-39.

GEORGE W. BARBER, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine.*

A New Host Plant and Locality Record for the Christmas Berry Thrips

The life history, habits and distribution of *Rhynchothrips ilex* (Moulton) have been discussed by Bailey (1936). The only host plant heretofore recorded on which it is known to breed is the Christmas berry or toyon, *Photinia arbutifolia* Lindl., which is limited in distribution to California in the lower Sierra Nevada foothills from Butte County to Mariposa County and in the coast ranges from Humbolt and Shasta counties south to San Diego. The thrips occurs over most of this area but is rarely found in the great valleys or in the high rainfall districts of the north coast. It is of considerable interest, then to record the discovery by the author of *Rhynchothrips ilex* (det. by S. F. Bailey) heavily infesting sugar-bush, *Rhus ovata* Wats. on the hot and dry eastern slopes of Mount San Jacinto, Riverside County, California, in June, 1939.

A number of cuttings of infested branches were brought back to the laboratory and a few observations were made, fig. 1. The damage to *Rhus* is similar to that on toyon but the leaves are more curled so as to give a conspicuous knotted appearance. The distortion changes the entire appearance of the plant. The larvae feed within the cavities they have created on the uppersides of the leaves, and the adults lay their eggs in these same pockets. The larvae are strikingly colored, with the head,

legs, two spots on the pronotum and tip of the abdomen dark, and the rest of the body a bright pale orange.

In an experiment to determine whether thrips from *Rhus* would live on toyon, both eggs and larvae were transferred to the toyon leaves. The method used was suggested by the more elaborate device developed by Francis Munger of the U. S. Department of Agriculture laboratories at Whittier for rearing citrus thrips. A small fresh leaf is placed between blotting paper on one side and a piece of cardboard in which a round hole is cut on the other side. This ensemble is in turn placed between two

FIG. 1.—Left, nearly normal leaves of sugar-bush; right, leaves in various stages of distortion caused by *Rhynchothrips ilex* (Moulton).

glass slides and clamped at each end. If the blotting paper is kept damp and the thrips placed in the cell formed by the cardboard, a leaf can be kept fresh for a long period of time and the life history of the thrips in its somewhat unnatural surroundings can be observed under the microscope. No difficulty was encountered in rearing second instar larvae through the adult stage on either sugar-bush or toyon. Lack of time precluded a careful check of the life history, however. Under laboratory conditions the prepupal instar lasted 2 to 3 days and the pupal instar less than a week. Adults continued to feed in their artificial cells for several weeks until the experiment was abandoned.—8-11-39.

R. M. BOHART, *University of California at Los Angeles.*

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Host Plants Harboring *Aplanobacter stewarti* Without Showing External Symptoms After Inoculation by *Chaetocnema pulicaria*

Work on the insect vectors of bacterial wilt of corn, caused by *Aplanobacter stewarti* (E. F. Sm.) McC., has indicated a consistent tendency for all field collections of the principal insect vector, the corn flea beetle, *Chaetocnema pulicaria* Melsh., to yield a certain proportion of beetles carrying the wilt organism, regardless of the conditions under which they have been collected. Considering the conditions under which some of these collections were made it seems improbable that the wilt-infested beetles they contained had had an opportunity to feed on infected corn locally, especially corn showing external symptoms of the disease, or that they could have migrated from other areas in sufficient numbers to account for the proportion of wilt-infested beetles found. The question therefore arises as to how these beetles became infested with the organism, especially since studies on the biology and seasonal history of the corn flea beetle have shown that corn is not necessary to its existence. During 1938 and 1939, at the Arlington Experiment Farm, Arlington, Va., a series of experiments was conducted with the idea of finding an answer to this question.

Adults of *Chaetocnema pulicaria* which had previously been confined in celluloid cages on infected corn in the greenhouse for several days were then similarly confined for about the same length of time on various species of Gramineae, after which they were removed from these plants. The beetles fed on the infected corn, the uninfected corn and the grasses. From 3 to 6 weeks later, no symptoms of bacterial wilt having appeared, parts of these plants having no feeding marks or visible extraneous matter upon them (no attempt was made to disinfect the external surface of this plant material) were macerated in a mortar and the juice thus expressed was used to inoculate susceptible disease-free sweet corn plants in the greenhouse. A few drops of sterile distilled water were added to the macerated plant material in some instances in order to get liquid inoculum. Inoculations with distilled water or with juice expressed from healthy plants of corn, wheat and certain grasses, as checks to which beetles had not had access, produced no symptoms of wilt. Typical symptoms of bacterial wilt were produced in susceptible sweet corn by inoculation with juice expressed from the following plants upon which adults of *C. pulicaria* had fed as described above: Corn (field, Golden Cross Bantam and Gill Brothers' Golden Bantam); crabgrass, *Digitaria* sp.; fall panicum, *Panicum dichotomiflorum* Michx.; Job's-tears, *Coix lacrymi-jobi* L.; Kentucky blue grass, *Poa pratensis* L.; orchard grass, *Dactylis glomerata* L.; redtop, *Agrostis alba* L.; Sudan grass, *Sorghum vulgare* var. *sudanense* (Piper) Hitchc.; wheat, *Triticum aestivum* L.; witchgrass, *Panicum capillare* L.; yellow bristle grass, *Setaria lutescens* (Weigel) F. T. Hubb. Although external symptoms of bacterial wilt apparently have not been reported on the host plants named above, except corn, Job's-tears and yellow bristle grass, it is not meant to imply in this paper that external symptoms of the disease might not occur on all of the host plants used in these studies if further tests were made for this purpose.

A total of 46 tests were made with juice from the species other than corn, which are listed above, and in 14 of these tests typical symptoms of bacterial wilt were obtained in the inoculated corn plants. In these tests 123 sweet corn plants were inoculated; in 25 of these plants typical symptoms of bacterial wilt appeared. In addition, three inoculations made with juice from Gill Brothers' Golden Bantam sweet corn (a very susceptible variety) which had been fed upon by infested beetles but which did not develop wilt symptoms, yielded typical symptoms in each of nine inoculated plants. Juice from fed-upon

but symptomless Golden Cross Bantam sweet corn (a resistant variety) produced typical symptoms of the disease in three of the four tests made, or in 6 of the 11 plants inoculated. Two out of four tests, or 3 out of 10 plants, inoculated with juice from fed-upon but symptomless field corn, yielded typical symptoms of the disease. The significance of these tests is emphasized by the fact that most of them were made during the winter months when it is more difficult to produce typical symptoms of bacterial wilt owing to abnormal or slow growth of the corn plants.

The presence of the wilt organism in the expressed juice of Kentucky blue grass, orchard grass and wheat suggested the possibility that the organism might not overwinter in the corn flea beetle, as previously reported, but instead that the beetles, upon coming out of hibernation in early spring, might become infested with the wilt organism by feeding on host plants harboring the wilt without showing any symptoms of it. Further evidence that the wilt organism overwinters in the corn flea beetle was obtained by producing typical wilt symptoms in susceptible sweet corn plants inoculated with inoculum made from adults of *Chaetocnema pulicaria* taken from emergence cages which were placed on several different species of grasses in the field in February. These cages were covered with black roofing paper and the vegetation in them died for want of light before the beetles emerged from the inclosed soil, thus rendering it very improbable that the beetles became infested by feeding after they had emerged. Three shell vials were inserted near the base in the south side of each cage for the positively phototropic adult beetles to enter. This method facilitated their removal from the cage after their emergence from the soil. Five direct inoculation tests were made with 5 lots of inoculum made from a total of 19 adults of *C. pulicaria* thus collected. These beetles were externally disinfected before being crushed in sterile distilled water. In one of these tests typical wilt symptoms appeared in all three plants inoculated with a culture made from seven adult beetles obtained April 18–27 from emergence cages as described above.

Although the occurrence of symptomless host plants of bacterial wilt of corn, as reported herein, does not indicate how significant they may be from the field standpoint, it seems highly probable that they occur under field conditions and that they may have an important relation to the abundance of wilt in corn. Explanations have been offered by other workers for variations in the abundance of wilt in sweet corn and field corn from year to year and also for its decreasing abundance in sweet corn within a season, but experimental data involving extensive surveys which would adequately confirm the validity of such explanations are not easily obtainable. It is not the purpose of this article to evaluate the explanations of variations in wilt abundance already given, but to call attention to the probable occurrence of symptomless host plants as another factor to be considered in explaining these variations, and to the potential significance of such plants in furnishing wilt organisms for the insect vectors to transmit to healthy corn plants. There appears to be much need for further information regarding the many factors involved before reliable forecasts and explanations of variations in the abundance of bacterial wilt of corn can be made.—8-16-39.

F. W. Poos, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine.*

Recovery From Excreta of the Pigeon of Viable Eggs of the Giant Thorny-Headed Worm of Swine

The Acanthocephalid intestinal worm parasite of swine, *Macracanthorhynchus hirudinaceau* (Pallas) Travassos, commonly known as the giant thorny-headed worm, is an important source of loss to hog raisers in many parts of America and of the world.

The microscopic eggs of this worm parasite voided with excreta of an infested pig may be carried by rainwater into the soil or into streams, where they may be swallowed by white grubs (larvae of *Phyllophaga* and related beetles) or by other insect larvae which serve as intermediary hosts. When swallowed by such insect larvae the embryos leave the eggs, pass through the wall of the alimentary canal and develop into encysted larval worms within the body cavity of the insect host. Here they remain during the rest of the larval period, and even during transformation of the insect through the pupa stage and into the adult beetle. When the insect host bearing larval cysts is eaten by a pig, the larval worms released by digestion of the cyst wall may attach themselves to the wall of the small intestine of the pig and continue their development to sexual maturity.

Beyond the simple cycle just described, however, the senior author was led by his earlier studies of this insect-propagated worm parasite of swine to question whether its ecological mobility may not be considerably extended by hitherto unrecognized interactions with ecologically associated organisms.

It had previously been shown experimentally (by the senior author, and hitherto unpublished) that eggs of this and of other worm parasites may be carried considerable distances on the soiled feet of birds. Another hypothesis remaining to be tested was whether eggs of the giant thorny-headed worm could survive passage through the alimentary canal of ecologically associated birds.

To open this phase of the problem, food contaminated with eggs of the parasite was given to the common domestic pigeon until the eggs appeared in excreta of the bird. On May 16, 1939, white grubs were fed small quantities of such egg bearing excreta, care to exclude the possibility of contamination with worm eggs from any other source having been rigorously observed. On June 19, fully developed larval cysts of the giant thorny-headed worm were found in the body cavity of the experimentally treated grubs. No cysts were found in grubs from the same stock which had been held as check material.

It appears, therefore, that pigeons and possibly other birds that forage in feed lots occupied or shared by pigs may transport, and disseminate in their own excreta, still viable eggs of the giant thorny-headed worm of swine which may have been swallowed with contaminated food picked up by them in such places.—8-21-39.

ROBERT D. GLASGOW and PAUL DEPORTE, *New York State Museum, Albany.*

Control of Blackflies (Simuliidae)

Pyrethrum extract in a petroleum oil solvent emulsified according to a formula approximating that of the New Jersey mosquito larvacide has proved in field tests to be highly effective for ridding

a stream of blackfly larvae, apparently without any direct harm to fish, to aquatic birds or to other associated aquatic vertebrates. Because of its general similarity, the New Jersey pyrethrum mosquito larvacide should be equally effective and equally harmless to aquatic vertebrates.

Neither minnows nor frogs in treated streams have given any observable evidence of excitement, nor any other indication of inconvenience occasioned by the larvacide. One frog in particular, which persistently resumed the same station at the margin of one of the treated streams but repeatedly swam to a rock in mid-stream on approach of the observer, remained clinging to this rock almost submerged during the passage of two successive waves of the larvacide employed in much greater concentration than would ordinarily be used. Yet this frog appeared to be wholly unaffected by and indifferent to the larvacide, and returned promptly to its post at the margin of the stream when the observer withdrew after the last wave of larvacide had passed.

A single treatment with such a pyrethrum larvacide has cleared a heavy population of blackfly larvae almost completely from nearly an eighth of a mile of stream; but, at the same time, it cleared the associated fish food species of insects almost as completely from the same section of the stream.

Cost of the treatment, while relatively moderate, would doubtless limit its use to the neighborhood of human habitations, or to places where other human values might justify the expenditure involved.

Loss of the fish food insect population, therefore, would be only occasional and local, and in practice would probably be of little ecologic consequence; for, through normal biotic pressure, such denuded local sectors of a stream would be quickly repopulated by migration from adjacent sectors, very largely from what might otherwise for lack of space be surplus reproduction, and thus without materially depleting the contributing parent populations.—8-21-39.

ROBERT D. GLASGOW, *New York State Museum, Albany.*

Thrips nigropilosus Uzel, a Non-Vector of the Yellow Spot Virus*

The first transmission tests of the spotted wilt virus, of which the yellow spot virus is a probable synonym,† with *Thrips nigropilosus* Uzel were not a success in Australia because the colony could not establish on infected tomatoes (Samuel *et al.* 1930). However, in Hawaii the insect was successfully bred on *Emilia sonchifolia* DC., which is the major weed host of the yellow spot virus, and hence conclusive data could be collected. Adults of *T. nigropilosus* and *T. tabaci* Lind., the latter being the sole known vector in Hawaii, from the colonies established on the same or similar infected source plants were likewise transferred to test plants. The materials and methods employed are similar to those described in detail in a concurrent paper.† All data are presented in table 1. Pineapple, spinach, celery, tomato, tobacco, potato, eggplant, *Datura stramonium* L., petunia and lettuce are all susceptible to the virus. None of a total of 668 *T. nigropilosus*, with several different sequences of host plants, transmitted the virus, leaving all of the 120 test plants noninfected, while *T. tabaci* freely became infective after feeding on the same or similar source plants. On considering the specificity of insects, generally speaking, for virus transmitting ability and the adequate number of samples tested, it can be safely concluded that *T. nigropilosus* is not able to become infective and is not a vector of the virus.

Table 1.—Transmission tests of the yellow spot virus with *Thrips nigropilosus*.

Source Plant	Test Plant	*Thrips nigropilosus*, Number of Test Plants		*Thrips tabaci*, Number of Test Plants	
		Tested	Infected	Tested	Infected
Emilia	*Emilia*	50	0	40	40
Emilia	Pineapple	5	0	—	—
Emilia	Spinach	5	0	—	—
Emilia	Celery	4	0	—	—
Emilia	Tomato	5	0	—	—
Emilia	Tobacco	3	0	—	—
Emilia	Potato	4	0	—	—
Emilia	Eggplant	4	0	—	—
Emilia	*Datura stramonium*	5	0	—	—
Emilia	Petunia	5	0	—	—
Emilia	Lettuce	4	0	—	—
Potato	*Emilia*	10	0	5	3
Eggplant	*Emilia*	6	0	3	2
Datura stramonium	*Emilia*	10	0	10	10

Preliminary transmission tests with *Hercinothrips femoralis* (Reuter) indicate that all of the 250 adults from the infected *Emilia* and celery source plants were unable to transmit the virus, while *Thrips tabaci* of the check lot freely became infective after feeding on the same source plants. It is of interest to note here that the nonvector relationship of *H. femoralis* was also demonstrated in the cases of peach yellows (Hartzell 1935) and curly top (Bennet & Wallace 1938).—8-27-39.

K. SAKIMURA, *Pineapple Experiment Station, Honolulu, Hawaii.*

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* Published with the approval of the Director as Technical Paper No. 125 of the Pineapple Experiment Station, University of Hawaii.

† Sakimura, K. Evidence for the identity of the yellow spot virus with the spotted wilt virus: Experiments with the vector, *Thrips tabaci* Lind. (To be published.)

Derris for Ants and Wasps

During the past 2 years the writer has obtained remarkable success in controlling carpenter ants, *Camponotus* spp., by means of derris power (4 per cent rotenone). No matter where the nest is situated or how extensive the infestation, if the powder can be placed where the ants must walk through it and thus get some of it on their bodies the colony can be exterminated rapidly.

An outstanding case was a house at Shawnigan Lake, north of Victoria, where carpenter ants had infested the building for several years. One wall,

indeed, was so badly damaged that, after the extermination of the colony, many timbers had to be replaced. Ants swarmed in the living rooms, and quantities of sawdust from their workings was swept up every day. The owner was advised to open the wall where the activities of the ants seemed to be most marked and to scatter derris powder in the opening so that it would fall down between the uprights. This was done and at the end of a week the owner reported that the ants had been completely controlled. On the wall being opened, several bushels of sawdust, dead ants and debris were removed.

During the past two seasons we have recommended derris in a number of other cases of infestation by carpenter ants with complete success attending in every instance. In cases of light infestation the ants usually disappear within 2 or 3 days. The writer has not had occasion to try this remedy against other species of ants.

Against wasps and hornets derris powder has proved superior to cyanide, in that no fumes are to be confined and it is adaptable to almost every situation. Everyone is aware of the difficulty of dealing with a wasp's nest built in the wall of a building, often in the wall of the front porch or steps. In such a case all that is necessary is to throw a handful of derris powder in the crack where the wasps emerge and, if it can be made to lodge in the opening so that the wasps will get some of it on their bodies as they pass through, the insects will generally be exterminated within 24 hours. We have destroyed small nests within 5 hours. It may be necessary in some cases to block all entrances except one and to place a small ledge of wood at the entrance hole to support the powder. This can be held in position with a dab of stiff glue, tanglefoot or putty. As to quantity, a handful of powder is ample. A wasp's nest in the ground was recently exterminated with 1 teaspoonful of derris. White-faced hornets seem rather more resistant to the powder than wasps, but a hornet's nest in a cherry tree was destroyed by me in 24 hours recently by throwing a handful of powder at the hole in the side of the nest.

An unusual case, with which we had to deal in 1938, was the destruction of a colony of honeybees which had made their hive under the shingles above the bow window of a dwelling in Victoria. This hive had been present for 2 years and the bees had become so numerous as to be a menace to the occupants of the house. All entrances between the shingles were stopped except one and into this opening derris powder was thrown in liberal quantity. At the end of a few days every worker was dead and the rest of the brood succumbed in due course as fast as it emerged.—9-27-39.

W. DOWNES, *Dominion Entomological Laboratory, Victoria, B. C., Can.*

The Effect of Previous Diet on the Toxic Action of Lead Arsenate to a Leaf-Feeding Insect

Many insects feed upon a variety of host plants, certain of which appear to be inferior to others as a diet. The effects of different diets of this type are often apparent in the rate of growth of the insects, the fecundity of the adults, the resistance to disease and even in the pigmentation of the individuals. These physiological variations have been noted from time to time in the case of the southern armyworm, *Prodenia eridania* (Cram.), which has been reared by the author in the laboratory for several years. It appeared possible, therefore, that other physiological changes may have occurred which would result in a change in the resistance of the insect to certain insecticides. A short series of tests was made to determine if the resistance of southern armyworms to an insecticide could be controlled by feeding certain species of plants.

Five lots of newly hatched larvae were selected at random from a large number of individuals of the same age, and each lot reared to the fifth instar on a different type of host plant. Two lots were fed on collard leaves, one on young, tender leaves and the other on very old, tough leaves. The remaining three lots were fed sweet potato, squash and polk weed (*Phytolacca rigida*) leaves. Some difference was noted in the rate of growth of the several lots of larvae but it was not great enough to appear to be a factor in this test.

When the larvae had developed to the fifth instar, they were fed tender collard leaves which had been dusted with lead arsenate. It was necessary to use the same foliage for all the larvae in these insecticide tests to avoid differences caused by any possible reaction which the foliage itself might have on the arsenical or on the digestive processes. The tests were made by feeding 10 larvae on a dusted collard leaf, approximately 1¾ inches square, in a Petri dish. At least six tests were made on the same lot of larvae over a period of several days, which was possible because all the individuals did not grow at exactly the same rate.

Table 1 records the results of the feeding experiments with the dusted collard leaves. Larvae which had been reared on polk weed were definitely more resistant to lead arsenate than those reared on collards. Not only was the mortality less among the larvae reared on polk weed, but the feeding on the leaves was definitely greater. The larvae reared on young collard leaves reacted to the arsenical in about the same way as those reared on old leaves but the remaining three lots of larvae were definitely more resistant. It would appear from these results that the resistance of armyworms to lead arsenate could be controlled to a large degree by rearing the larvae on certain species of plants.—9-20-39.

Table 1.—The toxicity of lead arsenate to fifth-instar southern armyworms reared on different kinds of foliage

Foliage	Number of Tests	Deposit* M/sc†	Feeding	Per Cent Kill in 48 Hours
Young collard leaves	6	100	Trace	98.5
	6	70	Trace	95.0
	6	50	Trace	91.5
Old collard leaves	6	100	Trace	95.0
	6	70	Trace	91.5
	6	50	Trace	66.5
Sweetpotato leaves	13	100	Moderate	53.0
	11	70	Moderate	39.0
	12	50	Normal	3.0
Squash leaves	6	100	Trace	30.0
	6	70	Trace	28.0
	6	50	Moderate	10.0
Polk weed leaves	6	100	Trace	15.0
	6	70	Moderate	0.0
	6	50	Moderate	0.0

* Lead arsenate dusted on collard leaves.
† Micrograms per square centimeter of leaf surface.

M. C. SWINGLE, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine.*

A Method for Studying the Fauna of Mushroom Manure*†

During extensive studies on the fauna of mushroom manure, various methods of separating both living and dead forms from the manure were tested. Techniques using light, heat, chemical repellents, separatory funnels, microscopic examination, or the rearing of the insects and mites in the manure, failed to meet the requirements, as it was found that only a low proportion of the animals contained in the manure, especially of those which were already dead, were exposed to view by these methods. Since the object of these studies was to determine not only the comparative abundance of the various insect and mite species, but also the relative proportion of live and dead animals after the normal heating of the manure, and after the application of various fumigants and other insecticides, other methods than the above were tried, and the following method finally was decided upon as giving the most nearly exact picture of the fauna of manure samples.

Briefly stated, the method consists in washing out the insects and mites from a given sized sample of the manure and examining the washings to determine the living and dead forms present. In the study of the fauna of the composting manure piles outdoors, samples were removed from definite restricted areas, since the comparative abundance of the various species seems to vary with their location on the pile. These samples were taken within a few inches of the surface of the pile, as the manure deeper than that is too hot for these animals to continue to exist. Indoors, after the beds had been filled with manure, and after the manure had, by bacterial decomposition, reached a temperature as high as 140 degrees F. in the upper beds and 125 degrees to 130 degrees in the lower beds, the samples consisted of random handfuls of manure taken from the surface inch of the bed, where all of the insects and mites were found to be concentrated by the heat within the bed. In many instances it was found that all or nearly all of these animals on the surface had already been killed by the heat.

Each composite sample from the surface of a bed was placed in a paper bag and was then removed to the laboratory for washing. This washing process consisted of the following: Approximately 150 grams of the manure within the bag was placed in a can the bottom of which was a 16-mesh screen. This can was then set down into a bucket containing 1 gallon of water to which had been added 10 cubic centimeters of a liquid wetting agent. *Vatsol OT*, 10 per cent aqueous, was used, but other neutral wetting agents were also found to be satisfactory. The manure was thoroughly stirred around in this "sudsy" solution for about 5 minutes until the animal life, the finer organic residue and the soil had been completely washed out into the bucket. The inner can was then removed and the coarser, cleaned manure was discarded. The solution in the bucket was allowed to settle for 5 minutes, when the supernatant liquid was poured off, leaving only about 500 cubic centimeters of the liquid which contained the settlings. This was poured into a beaker and allowed to settle as before; after 5 minutes the water was decanted from this down to the settled materials. For strictly quantitative readings it is necessary to pour the decanted water, with its finer materials, through a much finer screen than the 16 mesh, in order to retain the few insects which may have remained afloat. The coarser discarded material should also be thoroughly examined in this case.

To read this material, it was poured into a Petri dish to the depth of about one-sixteenth inch. A marker, such as a match stick or other small piece of wood, was dropped into the dish, extending radially from the side to the center, and the dish was then placed on the stage of a wide-field binocular microscope where it was easy to determine the kind, number and condition of the various mite and insect species present. Three dishes were read as characteristic of each composite sample taken from a bed. Over 200 composite samples were thus read, representing about 100 houses, and it was found that this method was much more indicative of the total manure population than were any of the other methods tried. Living and dead individuals of three species of springtails, and larvae of four species of Diptera, and six species of mites were observed in the samples examined.

This method is chiefly qualitative, but it is also quantitative to the extent that it gives a reasonably accurate picture of the comparative abundance of the species which are present and of the proportion of living and dead animals. It should prove useful for the sampling of mites and insects in moss, grain, straw, leaf mold, and organic and inorganic soils, and could be applied to the sampling of invertebrate fauna from the debris in the bottom of ponds and streams. Slime mold and other spores, as well as nematodes, have also been washed from the soil by this method.—10-2-39.

C. A. THOMAS, *Pennsylvania State College*, and J. L. HORSFALL, *New York, N. Y.*

* Authorized for publication on September 11, 1939, as Paper No. 921 in the Journal Series of the Pennsylvania Agricultural Experiment Station.

† Since this description was written, the writers have learned that Dr. B. B. Pepper, New Jersey Agricultural Experiment Station, has been using a checking method on mushroom insects which is essentially the same as that described here, and he has reported that he found the method very satisfactory.—C. A. T.

The Golden Codling Moth, *Carpocapsa pomonella* (L.) var. *simpsonii* Busck

In 1883, Matthew Cooke, late Chief Executive Horticultural Officer of California, collected what is probably the first specimen of this beautiful variety of the codling moth. This specimen, sent to August Busck under date of July 30, 1883, is in the collection of the U. S. National Museum. Simpson (1903) first records this variety in print. He makes the statement: "In 1900 the writer found one buff-colored moth which except for color, was like the common codling moth, on the trunk of a tree at Boise, Idaho. During 1901 four well-preserved specimens and eight badly worn specimens were secured. In 1902 six of these buff-colored moths were bred among 182 normal moths. In material collected in Idaho in the fall of 1902, from which about 30 moths emerged the following spring, five were of this variety. Mr. A. F. Hitt of Weiser, Idaho, and Mr. Alex McPherson tell the writer that they have noticed these buff-colored moths. Mr. Hitt in 1896 bred seven of these among fifty normal moths."

Specimens submitted by Simpson to August Busck for determination were described as the new variety indicated above (Busck 1903). Simpson calls attention to the fact that no gradations between this buff variety and the normal species have been noted.

In connection with the trapping of adult codling moths in monochromatic light traps, J. K. Ellsworth of the Division of Entomology, University of California, has frequently noted moths that were definitely paler than the normal type, which are no doubt the variety *simpsonii* of Busck.

The lighter forms are of a uniform shade of tawny or light golden-brown somewhat similar to the color of such related moths as the obliquebanded leaf roller, *Cacoecia rosaceana* (Harr.). Certain specimens have a brilliant metallic golden luster which is augmented by the more pronounced patch at the apices of the fore wings. From a series of captures numbering close to a million specimens Ellsworth has taken about 10 of these golden forms. I have before me four specimens varying considerably in size, but of the same golden color. Three were taken at Alviso, Calif., June 8–12, 1932, and one at Sebastopol, Calif., May 16, 1929. These moths are not merely newly-emerged specimens, or else they would appear in our breeding cages, nor are they to be called albinos because they are quite definitely pigmented. Of these four specimens three are females and one is a male as determined by Ellsworth.

Ralph H. Smith, who has long investigated this insect in the West, has told me that he first observed an occasional golden specimen among thousands reared in Idaho in 1921, and in 1923 he reared a number of specimens from pupae received from Colorado. Other references have been made to this variety in the West. From the evidence at hand, however, the golden form appears to have been reported only from the western states, but I may have overlooked references to it elsewhere.—10-13-39.

E. O. ESSIG, *University of California, Berkeley.*

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Swarm of *Thyanta custator* (F.)

On October 5, 1936, an enormous swarm of the common pentatomid, *Thyanta custator* (F.), was reported from Sioux Falls, S. D.

On October 8, 1937, this same species appeared in Sioux City, Iowa, in very large numbers, invading stores and houses. This infestation was reported as a scientific note in the JOURNAL OF ECONOMIC ENTOMOLOGY, February, 1939.

Because of the absence of the writer from Iowa in 1938, no observations were made in that year.

On October 5, 1939, another huge swarm of these insects flew into Sioux City, Iowa, from some unknown locality. High wind from the south on October 2 may have had something to do with this flight of the insects. In some portions of the city they were swept up in the stores and on the streets by the pailful. The bright lights of the business centers of the city appeared to attract them especially; the private homes were not invaded to any extent.

As far as I know, these annual migrations of the *Thyanta* have never been explained. Very few of this species are collected in this vicinity during the summer seasons. It seems a strange phenomenon that, year after year, an almost identical date is chosen by these pentatomids for their annual mass flight.—10-16-39.

C. N. AINSLIE,* *Sioux City, Iowa.*

A Collecting Net With a Detachable Zipper Bag

Several common methods of handling insect specimens collected by sweeping were tried in sampling field border insect populations. After short trials these methods were discontinued because too much time was lost in killing and removing the collected material from the bag. A more rapid method was devised by construction of a sweeping net with a removable zipper bag and a series of detachable bags to be used as needed. This net has proved very satisfactory for collecting samples in both woody and herbaceous field borders. Several hundred samples of 50 sweeps each were taken with this net during the summer of 1939. There was little loss of time between samples since it was necessary only to replace a detachable bag after each sample was taken.

The net used is similar to the ordinary sweeping net except that it has an apron on the inside to prevent the escape of very active insects and an open bottom with a zipper attachment to which detachable bags can be fastened. A small flap is provided on the inside to cover the small opening made by the union of the zipper ends. With the exception of the zipper arrangement the net is patterned after a net described by Williams (1918).

As many detachable bags as meet the convenience of the worker can be made at little cost. The writer has found that five such bags are convenient for sampling field border populations. This number permits sampling both sides of a field border and the fields adjacent without stopping to remove specimens. It also leaves a spare bag for any collecting that may be desired while the samples are in the killing jar.

The method of collecting with this net is briefly as follows. After a sample is taken the specimens are jarred into the bottom of the detachable bag. The bag is removed by closing the neck with one hand and opening the zipper and zipper flap with the other hand. Specimens are temporarily retained by sealing the bag with a cord to which a data tag is attached. The sample can be safely carried in this manner in a collecting kit or by hand until it is convenient to place it in a killing jar. After the specimens have been killed they can be easily removed by carefully inverting the bag. As soon as a sample has been taken a fresh bag can be zipped on the net and collecting resumed.

Cost of material for the net is nominal. A folding fish landing net frame with extension handle was used for the net described. Directions for constructing this net and the materials needed are given below. Fig. 1 shows details of construction. Fig. 2 shows the completed net with bag detached, and fig. 3 shows the bag assembled.

The following materials are required for making the collecting net:

1½ yards of heavy unbleached muslin, 36 inch width
One 12-inch zipper open at both ends and additional zippers for the number of detachable bags desired
4 large ordinary clothing snaps
Suitable frame
Strong thread

* Died, December 5, 1939.

Construct a pattern according to the measurements given in 1, 2 and 5 of fig. 1. Place 1 and 2 of fig. 1 on a double thickness of material and cut to pattern. Cut one piece using 5 as a pattern. Hem

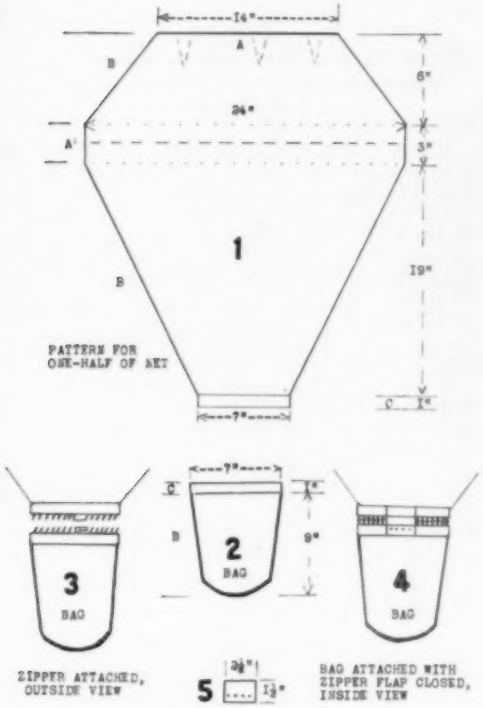

FIG. 1.—Diagram to be used as guide for making a collecting net with a detachable zipper bag.

both pieces cut from 1 at A and A′. Hem also the corresponding part of A′ on the opposite side of the pattern. Join both pieces cut from 1 at B and at the corresponding point on the opposite side of the pattern. Use flat felled seams. Make three one-half inch darts in each piece cut from 1, as indicated. Fold along dash line and stitch on dotted line. This makes a heading to fit the frame. Turn edge at C back one-half inch and attach the zipper band, using the part of the zipper with the slide.

Join both sides of 2, using flat felled seams and rounding the bottom of the bag. Turn edge at C back one-half inch and attach the remaining zipper band.

Hem the piece cut from pattern 5 on all sides and attach it to inside of 1 over the slide. Sew four large snaps on lower edge of 5 and their receptacles at the corresponding place on 2. Diagrams of the completed bag are shown in 3 and 4 of fig. 1. The net dismantled and assembled is shown in figs. 2 and 3. —10-28-39.

CHARLES A. DAMBACH, *Ohio State University, Columbus.*

FIG. 2.—Net dismantled.

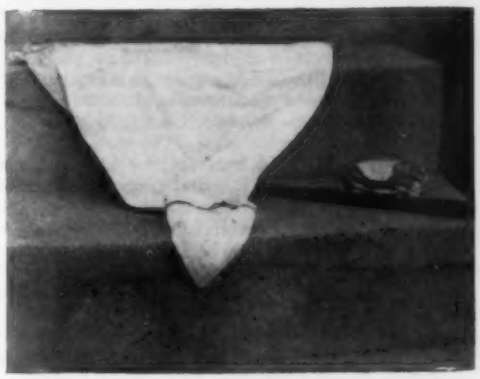

FIG. 3.—Net assembled.

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Neodiprion sertifer (Geoff.), a Pine Sawfly Accidentally Introduced Into New Jersey From Europe

Neodiprion sertifer (Geoff.) is reported to be a serious defoliator of pine in Europe, and outbreaks have been known to occur at irregular intervals in many countries on that continent.

In May, 1925, and again in May, 1926, members of the Bureau of Entomology and Plant Quarantine, U. S. Department of Agriculture, found sawfly larvae abundant and feeding on the foliage of *Pinus montana* and the variety *P. montana mughus* in New Jersey near Somerville, Somerset County, where an intensive eradication program was being carried on against the gypsy moth, *Porthetria dispar* (L.). It was not, however, until February, 1937, after a study of the sawflies in this region was undertaken, that the species was recognized as the European sawfly, *Neodiprion sertifer* (Geoff.).

Extensive surveys conducted in May, 1937, and again in May, 1938, disclosed that this sawfly is firmly established in Hunterdon, Mercer, Middlesex, Morris, Somerset and Union counties, N. J.

In September, 1937, several specimens of sawflies from Ohio submitted to the Division of Insect Identification, Bureau of Entomology and Plant Quarantine, by J. S. Houser, of the Ohio Agricultural Experiment Station, were identified as *Neodiprion sertifer*. In July, 1938, E. I. McDaniel, of Michigan State College Agricultural Experiment

Station, reported this species from Grayling, Mich., where it was attacking the mature growth of red (Norway) pine (McDaniel 1938).

Observations in New Jersey indicate that red pine (*Pinus resinosa*), Scotch pine (*P. sylvestris*), Japanese red pine (*P. densiflora*), jack pine (*P. banksiana*), Swiss mountain pine (*P. montana*) and Mugho pine (*P. montana mughus*) are most favored as food. Light feeding also has been observed on white pine (*P. strobus*) and Austrian pine (*P. austriaca*) where these trees were growing in close proximity to some of the other pines favored as food. No larvae of this species have been found on pitch pine (*P. rigida*).

Severe defoliation of some of the favored food plants was reported for the first time in 1937, and where artificial control measures have not been applied the infestations have continued in epidemic form.

The scarcity of pine plantations and the infrequent use of the hard pines as ornamentals in the communities surrounding the locality in which this sawfly first became established in New Jersey undoubtedly have been important factors in limiting or slowing up its dispersion. The spraying program carried on between 1921 and 1930 in the gypsy moth extermination project in New Jersey also must have aided in checking the infestation of this insect. Adhesives were used in the lead arsenate sprays, and plantations of conifers as well as the hardwoods were sprayed.

This species has one generation annually. The adults emerge generally in September and October, and the females deposit their eggs singly in slits in needles of the current year's growth. From 1 to 10 or more eggs may occur in a needle. The winter is passed in the egg stage, and hatching occurs late in April or early in May, depending upon the season. The larvae are gregarious and feed on the mature foliage, at first eating along the edges of the individual needles and later devouring all the needles on one branch before migrating to another. They become full grown late in May or early in June and spin most of their cocoons in the duff beneath the trees, although sometimes cocoons are spun on the twigs of the food plant. Such cocoons were particularly noticeable on red pine beneath the male flower catkins.

The adults are 7 to 9 millimeters in length and rather stout bodied, particularly the females. The males have the antennae feathery, head and thorax black, the abdomen more or less blackish above and reddish brown beneath and the legs reddish brown. The females are yellowish brown, with the antennae, except basal segments, the eyes and the metathorax blackish. The eggs just before hatching are whitish, 2 millimeters in length and elongate-oval in shape. The full grown larvae are about seven-eighths inch in length. They are dirty grayish green with a longitudinal dorsal line of a lighter shade; laterally there are two whitish lines bordering a stripe of very intense green or sometimes blackish, which has a tendency to break up into spots; the head, thoracic legs and dorsum of anal segment are black. Arising from the dorsal and pleural areas of the body are many short black setae, those on the dorsum being arranged in transverse rows. The cocoons are light brown, of a fine texture though tough, and are 8 to 10 millimeters in length with rounded ends.—10-26-39.

J. V. SCHAFFNER, JR., *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine.*

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Comstock's Mealybug, *Pseudococcus comstocki* (Kuw.), on Apple in Ohio

Hough (1925) and others have reported Comstock's mealybug, *Pseudococcus comstocki* (Kuw.), attacking apple in several eastern states, but to the writer's knowledge such attacks have not been reported west of the Alleghenies. In August of 1939, specimens of this mealybug were received from an apple orchard in southern Ohio. About 60 acres were found to be infested, and 80 large Grimes trees suffered almost a total loss of crop as far as a commercial pack was concerned. The salability of the fruit was damaged by the heavy growth of a black fungus following honeydew deposition by the mealybugs. Frequently, the fungus covered more than half of the apple and was very tough and difficult to remove. When growing about the stem end of the apple, it was frequently followed by a soft rot. We are indebted to the Division of Insect Identification, Bureau of Entomology and Plant Quarantine, U. S. Department of Agriculture, for a positive identification of this mealybug.—10-28-39.

C. R. CUTRIGHT, *Ohio Agricultural Experiment Station, Wooster.*

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The Propagation and Introduction of *Coccophagus heteropneusticus* Comp., a Parasite of Lecaniine Scale Insects

In 1934–1935, several species of parasites and predators of the black scale, *Saissetia oleae* (Bern.), were collected in South America and shipped to California by Harold Compere, foreign explorer of the University of California Citrus Experiment Station (Compere 1939).

One of the most common parasitic species was *Coccophagus heteropneusticus* Comp., which ranges from tropical Brazil to temperate Argentina. This is a gregarious parasite of various lecaniine scale insects. Compere found it attacking *Saissetia oleae* and *S. hemisphaerica* (Targ.) in South America. In the insectary at Riverside it reproduced on *Coccus hesperidum* L. and *C. pseudomagnoliarum* (Kuw.)

The propagation of this species and its subsequent liberations in large numbers became possible only when it was found that the male sex developed for the most part of the life cycle under entirely different conditions than the female.* The circumstances of this discovery have been described previously (Flanders 1937). In spite of the fact that *Cocco-*

*This fact is correlated with the production of males from unfertilized eggs. All of the evidence available indicates that the male sex in the order Hymenoptera develops from unfer-

phagus heteropneusticus develops successfully on several species of scale insects, the lack of a niche† in the Californian environment suitable for it appears to have precluded its establishment.

The black scale in the South American shipments was abundantly parasitized by *Coccophagus heteropneusticus*, indicating that this host in its South American habitat was very susceptible to parasitization. Dissections of black scale parasitized in the laboratory showed no indication of any host defensive reaction, such as phagocytosis.

The life history in black scale was studied and it did not appear unlike that of other *Coccophagus*. The incubation period of the egg was 3 days, the larval period 9 days and the pupal period 8 days, at a temperature of about 80 degrees F. When immature black scale is parasitized by *Coccophagus heteropneusticus*, the derm of the mid dorsal region of the scale becomes dark. This discoloration appears when the parasite is in the third instar. On the other hand, when soft scale, *Coccus hesperidum*, is the host, no discoloration is apparent.

The third instar of solitary individuals developing in the immature black scale forms a membranous cocoon. This cocoon is distended with air obtained through connections with the hosts' tracheae. The larva is thus protected from the moist viscera of the host. Pupation, however, does not occur until the viscera has been consumed or has become desiccated.

The life history was observed to be unusual in that the eggs under certain conditions were always deposited in the lumen of the midgut of the black scale. If such eggs hatch, the larvae must immediately work their way into the body cavity of the host, for they were rarely found in the midgut.

In one experiment, to determine the incubation period of the eggs, a potato sprout well infested with half grown black scale was cut and placed in water. The scales were then exposed to the parasites for several hours. Dissections were made at intervals over a period of 11 days. Eggs were found only in the midgut. Apparently none had hatched for no larvae were found. The embryonic development was also incomplete. Many immature scales that had apparently ceased to develop were removed from the rearing cages and examined. In nearly every specimen parasite eggs were found in the midgut. These eggs appeared to be disintegrating. This may have been because the hosts were not developing under normal conditions.

When oviposition takes place in mature black scale the parasite eggs are deposited less frequently in the midgut, possibly because of its relative decrease in diameter. Likewise, when *Coccus hesperidum* is the host, the eggs are deposited free in the body cavity. In *C. hesperidum*, however, some eggs were found encysted by phagocytes. In each case, however, the embryo had completed its development. The fact that phagocytosis was not observed in black scale indicates that it is a more suitable host than *C. hesperidum*. The predilection of the female for ovipositing in the midgut of a host in which only the body fluids provide a suitable medium for development appears to be an extraordinary aberration of instinct.

It was the rearing of this black scale parasite from mealybugs collected in Argentina that first revealed the phenomenon of divergent development of the sexes. In the routine recording of the parasite species emerging from the South American material as it was received, a remarkable situation occurred. In the shipments of black scale in which parasites of mealybugs were not included, nearly all of the specimens of *Coccophagus heteropneusticus* were female. In later shipments, which included parasitized mealybugs, the males predominated two to one. The importations from Argentina contained the citrus mealybug *Pseudococcus citri* (Risso) as well as black scale. Although insectary investigations had definitely shown *Coccophagus heteropneusticus* to be a primary parasite of black scale, more parasites were reared from the mealybugs than from black scale. The parasites from the mealybugs, however, were invariably males whereas those from the black scale were nearly all females. The males obtained from mealybugs mated readily with females obtained from black scale. Males that occasionally issued from black scale were identical with those from the mealybugs except in size, the latter being much larger and more robust.

Further examinations showed that the males were developing as ectoparasites on *Anagyrus pseudococci* Girault, an internal parasite of *Pseudococcus citri*. At first this was considered to be a case of accidental parasitism induced by unusual conditions, comparable to that noticed by Timberlake (1913) with regard to *Coccophagus lycimnia* (*lecanii*). Later it was noticed that the males of the species were persistently and regularly ectoparasitic, in sharp contrast to the endoparasitism of the females. These characteristics implied a marked difference in larval morphology, and such a difference proved to be the case.

The striking differences in the mode of development and in the appearance of eggs and larvae of progeny from the same parent before and after fertilization are given in the following parallel columns.

PROGENY FROM UNMATED FEMALE HYPERPARASITIC DEVELOPMENT	PROGENY FROM SAME FEMALE AFTER MATING, PRIMARY DEVELOPMENT
Oviposition	
Eggs firmly attached to outer surface of primary larva which has constructed its cocoon within a scale or mealybug; upon hatching the larvae feed ectoparasitically upon the primary inhabitant.	Eggs deposited free in the body fluids of black scale; upon hatching the larvae feed endoparasitically.
Egg	
Ovoidal, posterior end drawn out at time of oviposition into a pedicel-like process by which the egg is attached to the integument of a primary larva within the coccid.	Elongate, slightly arcuate and more slender posteriorly, a typical *Coccophagus* egg.

tilized, haploid eggs and that the female sex develops either from unfertilized diploid eggs (thelyotoky) or from fertilized haploid eggs which after syngamy are diploid.

† Niche: The function (occupation) of an animal in its biotic environment, particularly in relation to food and enemies. (*Animal Ecology*, by Charles Elton.)

First Larval Instar

Comparatively thick, the tracheal system with four open spiracles. Larvae found adhering to the dry outer surface of a primary inhabitant of the coccid.	Comparatively slender, the tracheal system a simple unbranched loop. Larvae found free in body fluids of the coccid.

Second Larval Instar

Six open and two rudimentary spiracles present and comparatively few tracheoles. Larvae feeding on surface of primary inhabitant.	No spiracles present, tracheoles numerous. Spiracular trachea truncate. Larvae free in body of coccid and feeding upon its body contents.

Third Larval Instar

Nine pairs of open spiracles.	Nine pairs of open spiracles.

Adults

Always of the male sex.	Always of the female sex.

Before ovipositing in a black scale, the parasite makes a brief preliminary inspection of the prospective host by examining it with her antennae. If the preliminary inspection is satisfactory, she inserts the ovipositor through the dorsum of the scale and quickly probes in the host's body before depositing an egg. When ovipositing in a mealybug "mummy" the female inserts the ovipositor at any point on the exposed surface.

The deposition of male eggs by unfertilized females on prepupae or pupae within mummified mealybugs can be observed by the removal of an end of the mummy, the contents thus being exposed.

In secondary parasitism, as contrasted with primary parasitism, there is less mortality during development and less variation in the time required to complete the life cycle, other things being equal. The larval stage in lecaniine scales may be prolonged either because of the necessity of waiting for the body fluids of the hosts to dry or because the host is less nutritious. The prolongation of female development is of great advantage in the establishment of a species like *Coccophagus heteropneusticus* in that it increases the chance of mating. The male progeny of early females can mate with the late emerging females.

In soft scale, *Coccus hesperidum* the immature stages of *Coccophagus heteropneusticus* females of the same age may vary in stage of development from second instar larvae to pupae. At temperatures of about 80 degrees F., the minimum life cycle was 20 days for both males and females. The size of the adults is determined to a large extent by the amount of food available. The males may be fully as large as the females.

Fertilization results in a complete transformation of the oviposition instinct of the female from that of an obligatory secondary parasite to an obligatory primary parasite. Since the male larva of *Coccophagus heteropneusticus* is adapted to a dry environment, a male egg deposited in the body fluids of a primary host by an unmated female will not hatch.

The deposition of eggs in the midgut of black scale can be explained by the fact that the wall of the midgut in lieu of a primary host furnishes a membranous tissue suitable for the attachment of the male eggs. In the experiment cited above it is probable that the eggs found in the midgut of the scale were deposited there either by unmated females or by mated females with unactivated spermathecae.

Aberrations in oviposition are likely to occur in those species of aphelinids which have the following types of male development:

I. Indirectly‡ hyperparasitic—feeding externally. Example: *Coccophagus trifasciatus* Comp.
II. Indirectly hyperparasitic—feeding internally. Example: *Prospaltella perniciosi* Tower
III. Directly hyperparasitic—feeding externally. Example: *Coccophagus heteropneusticus* Comp.
IV. Directly hyperparasitic—feeding internally. Example: *Coccophagus rusti* Comp.

In the case of *Coccophagus rusti*, the unmated female may deposit male eggs in the body fluids of the secondary host. Such eggs hatch but the young larvae cannot develop even when the primary host is present.

Although many generations of *Coccophagus heteropneusticus* were reared in the insectary, only one generation was observed to occur in the field. Thousands of mated females were liberated in various parts of southern California. The entomologist (Howard Lorbeer) of the Fillmore Citrus Protective District states in his annual report for 1936 that he reared and liberated in citrus groves over 600,000 specimens.—10-27-39.

S. E. FLANDERS, *Citrus Experiment Station, University of California, Riverside.*

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‡ Indirect parasitism is that type of symbiosis in which a secondary parasite inhabits a host insect upon which it itself is incapable of breeding in order that it may attack any primary parasite which subsequently becomes available (Smith 1916).

JOURNAL OF ECONOMIC ENTOMOLOGY

Official Organ American Association of Economic Entomologists

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After Four Years

THE current issue marks the completion of 4 years in the life of this publication under the present editorship. During this period, considerable time and effort have been devoted to expanding the JOURNAL OF ECONOMIC ENTOMOLOGY to meet new conditions of printing and typographic style. The December issue brings the total number of pages for Volume 32, with the index, to over 900. From the standpoint of subject matter and word count, the current volume is one of the largest in the history of the publication; 100 pages more than Volume 31, which was larger than the preceding volume.

Although some members of the American Association of Economic Entomologists may regard the revision of format that took place in 1938 as the most significant change experienced by the JOURNAL in the past 4 years, this probably does not rank in importance with the less obvious changes resulting from the establishment of the Publications Committee, known first as the Advisory Committee.

This Committee, members of which since its formation have read and critically evaluated papers submitted to the JOURNAL for publication, began operations in 1936 with a minimum of difficulty and has functioned effectively and with increasing smoothness to the present time. That the somewhat radical changes indicated by establishment of this Committee have been accepted without friction is evidence that the membership of the society represents a group of broad-minded, cooperative individuals working for the good of entomology rather than for selfish personal interests.

Because of the pressure of other duties, with this number the present Editor is terminating his official connection with the JOURNAL. In retiring, he wishes to express his appreciation to the members of the society for bearing with him during the 4-year period, accompanied as it was with changes of policy and format.

He wishes also to point to the importance of the JOURNAL as a vital unifying agency of the American Association of Economic Entomologists and as a means for disseminating significant entomological findings throughout the scientific world. With no disparagement to the benefits of the society's annual meetings, attention may be called to the fact that, whereas the Association meets but once a year, the JOURNAL reaches its members six times each year and, more than any other one agency, helps to keep the society virile and progressive. In addition, it extends into other fields of science and exerts in those fields an influence which even an unlimited number of societal or branch meetings could not exert.

Throughout the past 4 years it has become increasingly apparent to the Editor that the JOURNAL is deserving of added financial support from the society. The year by year cumulative importance of economic entomology has resulted in the submission to the JOURNAL, directly and through national and sectional meetings, of more and more papers worthy of publication. In spite of increases in the total word count of articles printed in 1938 and again in 1939, the publication of current contributions and of papers of the national and sectional meetings still lags behind the date of composition and acceptance. If the papers of Association members are to reach the stage of publication more promptly than at present, additional funds must be allocated to meet the costs of printing, engraving and editorial assistance. Earlier publication of papers necessitates an increase in the size of the JOURNAL, which in turn is impossible without a corresponding increase in publication costs.

The retiring Editor is keenly appreciative of the support given by the Publications Committee in the past 4 years. He hopes that this Committee, in its inception an experiment in publication procedure, will be retained by the Association and that earnest consideration will con-

tinue to be exercised in the selection of this Committee's members. More than any one individual or any other group of individuals, members of the Publications Committee determine the character of the papers by which the economic entomologists are known to the world. The Editor is appreciative also of the cooperation given by officers of the Association, authors of papers, and active members of the JOURNAL staff, the Associate Editor, the Business Manager and the Assistant to the Editor. Upon the occupant of the last office, recognized first in 1937 and unofficial for a year before that, has fallen much of the detailed editorial work of the JOURNAL.

It is the earnest hope of the retiring Editor that members of the Association will give to the new Editor, whoever he may be, the intelligent cooperation they have given the editorial staff throughout the past 4 years. The task of the JOURNAL Editor is not an easy one. It requires more time and attention than most members realize.

In the first half century of its existence, the American Association of Economic Entomologists has progressed far beyond the expectations of its founders. A virile publication, intelligently edited, has a vital part to play in the continued progress of the society. At the beginning of the Association's second half century the present Editor delivers into other hands, with confident hopes for the future, the guidance of the society's official publication.—12-12-39.

BOOK REVIEW

Destructive and Useful Insects, Their Habits and Control, by C. L. Metcalf and W. P. Flint, Second Edition. xvi+981 pp. 584 text figures. McGraw-Hill Book Co., Inc. New York, 1939.

The first edition of this generally useful work has been a standard reference volume in the reviewer's library for the past decade. The second edition adds greatly to the scope and comprehensiveness of the original and must be ranked as a thorough-going, reliable digest of economic entomology. The large number of investigators in various parts of the United States and the inevitable introduction of injurious insects has necessitated extensive additions and changes in the text of the first edition.

The authors have taken advantage of the revision to include keys to the insect orders and the immature stages, the latter most difficult to identify and yet of greatest importance in the early recognition of pests in the field. The keys will be especially useful to the student and a valuable aid to the identification of many species. The discussion of insects as disseminators of plant diseases has been greatly extended, and the scope and importance of this phase of entomology is well indicated by the tabulated summary of certain insect-borne diseases of plants. The chapters dealing with morphology, internal anatomy and physiology and development of insects have been brought down to date in terminology and comprehensiveness, this being most evident in the discussion of internal anatomy and physiology.

The economic entomologist will find in the 75 pages of the chapter on insect control, expanded from 50 pages in the first edition, a most useful compendium of our present knowledge of insecticides and means of controlling insects. The extent of this revision is indicated in more detail by the 2½ pages on derris, the nearly 4 pages on oils and emulsions, and the 15 pages on fumigants, the text on these three important topics being practically twice as extended as in the first edition. Each discussion of an important insecticide includes a brief statement of its history, its chemical and physical nature, the insecticidal principle, its field of usefulness, dosages, method of preparation for use, and compatability and incompatability with other spray materials, all important practical points. The table of median lethal doses on page 242 and tables xi and xiii on pages 247 and 261, respectively, are desirable additions to a book replete with valuable data.

The second and larger part of the volume, generally classed as economic and dealing with the pests of various crops or those troubling domestic animals or affecting the health of man, has been rearranged to conform to a system outlined on page viii of the preface. The various species are arranged under these heads in the sequence followed in the listing of the orders of insects, thus aiding in the ready location of information in relation to any one species. Furthermore, the accounts of individual insects or groups of insects are prefixed by numbers followed by others in parentheses which refer to the same insect in other groupings. It seems to the reviewer that page citations rather than arbitrary numerals are somewhat preferable.

Naturally a number of new species appears in this section of the book, such as the white-fringed beetle, Asiatic beetle, Asiatic garden beetle, European bark beetle, Mediterranean fruitfly, American screwworm and others which have become established in the country in the past decade or which have been recognized as distinct from earlier known species. The subtitle dealing with lawn and pasture insects is a brief recognition of the increasing importance of turf pests in suburban areas. The more than 20 new figures add materially to the value of a well illustrated work. For example, the identification of lawn grubs is greatly facilitated by reference to fig. 402. The authors have adopted the hyphen for compound names which are taxonomically incorrect as in scorpion-fly, since the insect is not a true fly, and have printed as two words the taxonomically correct names, such as house fly.

This book contains about 20 per cent more material than the first edition. Relatively few pages have escaped changes in the new edition. Its value is

greatly increased by the detailed index of 70 pages listing approximately 7,000 items. This index gives an idea of the immense amount of detail in writing such a volume.

The book is a necessity to all who would keep abreast of entomological developments in America. The student working with this volume has a most excellent guide in the widely diversified phases of insect activity. Librarians and custodians of general reference literature will find many of their needs met by this truly standard work. The authors are to be congratulated on producing such a generally acceptable contribution to entomological literature.—9-5-39.

E. P. FELT, *Bartlett Tree Research Laboratories, Stamford, Conn.*

OBITUARIES

Harold Francis Willard, 1884–1939

In the death of Harold Francis Willard which occurred in Honolulu, Hawaii, on August 18, 1939, the Bureau of Entomology and Plant Quarantine, U. S. Department of Agriculture, lost one of its outstanding workers and his associates a loyal and sympathetic friend.

Mr. Willard was born in Neillsville, Wis., on February 21, 1884. Following his graduation from Massachusetts Agricultural College in 1911 he accepted a position in Honolulu as an instructor in agriculture and practical fruit growing at Mills College, a military school for Polynesian and Oriental students. Approximately 3 years were devoted to this work, after which he resigned to become a homesteader of government land in and about Haiku, Island of Maui.

In 1916 Mr. Willard entered the Bureau of Entomology and remained continuously in that Bureau until his death. He was associated with E. A. Back and C. E. Pemberton in the early research work in Hawaii on the Mediterranean fruitfly and melonfly and was in charge of these activities over a period of years. Mr. Willard, from the standpoint of his research work, is perhaps best known as the result of a series of papers reporting on the field parasitization of the Mediterranean fruitfly by imported natural enemies. These covered the period from 1918 to 1924 and the last one published in 1937 gave a complete record of parasitization by years as well as extensive data regarding the effectiveness of the parasites against the pests in different fruits for the years 1914 to 1933 inclusive. No comparable record is available for any other biological project. With Mr. Pemberton he published an extended account of the biology of fruitfly parasites, and his interest in this subject led to a later study on the parasitization of the pink bollworm. His work as a regulatory official in the enforcement of certain provisions contained in the Federal Mediterranean Fruitfly and Melonfly Quarantine, no. 13, was outstanding and he enjoyed in an unusual degree the confidence of the growers, shippers and transportation officials.

Mr. Willard was married in 1911 to Miss Mary Hyatt of Leominister, Mass., who preceded him in death in 1935. Since that time he has been in failing health and it was only his indomitable will and courageous outlook on life which enabled him to carry on in spite of his physical condition. Surviving are his son, Harold Francis, Jr., of Honoulu, and three brothers and two sisters, all living in Massachusetts.

Harold Francis Willard

He was a member of the American Association of Economic Entomologists, the Entomological Society of America and the Hawaiian Entomological Society. In the last named organization he took an active interest, serving as its Secretary for many years and as its President in 1926. He took an active interest also in the Masonic Lodge, the Lion's Club, and the religious and civic life of the community in which he lived.—11-19-39.

ARTHUR C. MASON
E. R. SASSCER

Bullion Alphonse Osterberger, 1901–1939

Bullion Alphonse Osterberger died on May 20, 1939, in Baton Rouge, La. He was born at Hope Villa, East Baton Rouge Parish, La., December 6, 1901.

He received the degree of Bachelor of Science in Agriculture from the Louisiana State University in 1926, and the degree of Master of Science in Zoology and Entomology in 1930.

In 1930 he married Miss Mildred Sorrells of Grayson, La.

During the scholastic year of 1936–1937, Mr. Osterberger attended the Kansas State College of Agriculture and Applied Science at Manhattan, Kan., for advanced work in entomology.

Surviving Mr. Osterberger are his wife, Mrs. Mildred Osterberger; one son, Leroy; his mother, Mrs. A. V. Osterberger; two sisters, Mrs. B. C. Vignes and Mrs. Gordon Ronaldson; and five brothers, C. L., K. E., A. V., Nolon and Sheldon.

Mr. Osterberger began his work with the Louisiana Agricultural Experiment Station as a student assistant to the late Dr. W. E. Hinds in the studies on the control of the surgarcane borer by the use of the parasite, *Trichogramma minutum* Riley. After graduation he assumed the duties of Assistant Entomologist at the Louisiana Agricultural Experiment Station, and continued his work with sugarcane insects, later becoming associated with Dr. Herbert Spencer. With Dr. Hinds and Dr. Spencer, he published several papers on the value of *Trichogramma minutum*. Later his studies included the sugarcane beetle and the sugarcane rootstock weevil.

Mr. Osterberger was a member of the American Association of Economic Entomologists, Cotton States Entomologists, Louisiana Entomologists, Kansas Entomological Society and Texas Entomological Society.—11-22-39.

C. O. EDDY

CURRENT NOTES

BIOLOGICAL SURVEY OF NEW HAMPSHIRE

The recently established Biological Institute of the University of New Hampshire is planning a biological survey of New Hampshire. Dr. C. Floyd Jackson, Professor of Entomology and Zoology and Dean of the College of Liberal Arts, is director of the Institute.

Staff members, working in their respective fields, will carry on the work of the survey, which will include study of mammals, birds, amphibians, reptiles, fish, insects, ornamental plants and shrubs, fungi and algae, trees and woods, and rocks and minerals.

NATIONAL PEST CONTROL ASSOCIATION CONVENTION

The Seventh Annual Convention of the National Pest Control Association was the most successful, from the standpoint of attendance, interest, program and entertainment, since its organization 7 years ago, according to the report of attendants. Furthermore there was a greater interest by entomologists than at any previous convention.

The convention was held in the Hotel Pennsylvania, New York, N. Y., November 23–25. Registration totaled 483; at several sessions appreciably more than 500 were in attendance. Entomologists included Neely Turner, Connecticut, W. E. McCauley, Illinois, T. J. Headlee and C. C. Hamilton, New Jersey, J. J. Davis, Indiana, C. E. Palm and R. W. Leiby, New York, F. L. Campbell, Ohio, and Arthur Gibson, Canada. The U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine, was represented by P. N. Annand, E. A. Back, N. F. Howard, R. C. Roark, T. E. Snyder, R. A. St. George and E. R. Sasscer. The Bureau of Biological Survey was represented by seven staff members, as follows: W. E. Riter, George B. Lay, E. M. Mills, D. A. Spencer, G. W. Dyar, W. W. Dykstra and H. A. Merrill. C. L. Williams represented the U. S. Public Health Service.

Aside from industry problems, the following pertinent subjects were included in the talks and clinics: fumigation, rats, clothes moths and mothproofing, termites, general household pests and the chemistry of insecticides.

The papers presented will be published in *Pests*, *Soap* and *Chemical Industries*. The clinic questions and answers will be published in the *News Letter* of the National Pest Control Association.

APPOINTMENT OF HOWELL

Dr. Dariel E. Howell was appointed Assistant Professor of Entomology at Oklahoma Agricultural and Mechanical College, September 1, to take the place of Dr. L. E. Rozeboom, who resigned to accept a position in the Department of Medical Entomology at Johns Hopkins University. Dr. Howell will have charge of investigations dealing with insect and tick transmission of bovine anaplasmosis, and will teach courses in medical entomology and pest control. His undergraduate and graduate work was done at the University of California, where he received his Ph.D. degree under Dr. William B. Herms.

STAFF ADDITIONS TO *Biological Abstracts*

Two new editors have recently been added to the staff of *Biological Abstracts*. Dr. Joseph N. Knull of Ohio State University is to serve as the editor of the section of Coleoptera. A. B. Gurney will serve as editor of the section on Orthoptera.

RETURN OF HIXSON TO OKLAHOMA

Professor Ephriam Hixon returned to Oklahoma Agricultural and Mechanical College, September 1, following a Sabbatical leave of absence of a year to take graduate work at Iowa State College.

EUROPEAN JOURNALS AND THE WAR

The non-receipt by a subscriber of any European chemical or other scientific journal seriously needed as research material should be promptly reported to the American Documentation Institute.

The Cultural Relations Committee of ADI, which cooperates closely with the Cultural Relations Division of the Department of State, is working on this problem, and hopes to be able to surmount such war obstacles as interrupted transportation, embargoes and censorship, which so grievously affected the progress of research during the last war.

The principle should be established, if possible, that the materials of research having no relation to war shall continue to pass freely, regardless of the countries of origin or destination.

Reports, with full details of where subscription was placed and name and address of subscriber,

volume, date and number of last issue received, should be addressed to:

American Documentation Institute
Bibliofilm Service
Care of the U. S. Department of Agriculture Library
Washington, D. C.

SHELFORD ACTING HEAD

New acting head of the Department of Zoology at the University of Illinois is Professor Victor E. Shelford. Assistant Professor C. Ladd Prosser, recently of Clark University, has been placed in charge of general physiology and Hurst H. Shoemaker has been made instructor. Frank B. Adamstone has been promoted to an associate professorship, B. Vincent Hall to an assistant professorship and Lester Ingle to an associateship.

REPORT OF THE ROCKY MOUNTAIN CONFERENCE OF ENTOMOLOGISTS

The Fifteenth Rocky Mountain Conference of Entomologists was held at the University of Colorado Science Lodge, about 28 miles west of Boulder, Colo., August 13–18, 1939. One hundred twelve, the largest attendance in the history of the Conference, enrolled. These represented 18 states, the District of Columbia and two provinces of Canada. Following is a list of those interested in entomology who attended the programs.

Colorado: Hugo G. Rodeck, Boulder; Urless Lanham, Longmont; Miriam A. Palmer, Fort Collins; Wayne Howe, Fort Collins; J. A. Beal, Fort Collins; N. D. Wygant, Fort Collins; Maurice T. James, Fort Collins; Gordon Alexander, Boulder; C. A. Connaughton, Fort Collins; Sam C. McCampbell, Fort Collins; W. G. Gambill, Jr., Boulder; Allan M. Hull, Boulder; Norman LeVeque, Boulder; Harold M. Ratcliff, Estes Park; Leigh E. Chadwick, Colorado Springs; Bob Potts, Colorado Springs; C. K. Collins, Fort Collins; Theodore Krueger, Denver; George H. Brown, Colorado Springs; Donald DeLeon, Fort Collins; C. R. Jones, Fort Collins, Al Connelly, Fort Collins; George M. List, Fort Collins; Calvin Massey, Wheatridge; Louis G. Davis, Pueblo; Max C. Grandy, Longmont; John L. Hoerner, Fort Collins; Ann Carmichael, Fort Collins.

Kansas: George A. Dean, Manhattan; E. G. Kelly, Manhattan; Roger C. Smith, Manhattan; R. T. Cotton, Manhattan.

Pennsylvania: Gerald J. Stout, State College.

Arkansas: Mrs. Minnie J. Armstrong, Fort Smith.

Arizona: Loyd L. Stitt, Tempe.

Washington, D. C.: R. T. Stevenson, F. C. Craighead, M. P. Jones.

Iowa: Chas. H. Richardson, Ames; F. B. Paddock, Ames.

Idaho: James C. Evenden, Coeur d'Alene.

Nebraska: F. W. Childs, Omaha.

Oklahoma: Ephriam Hixson, Stillwater; C. F. Stiles, Stillwater.

Canada: Douglas Dickson, Vernon, B. C.; George R. Hopping, Vernon, B. C.; A. S. West, Jr., Fredericton, N. B.

Texas: C. C. Doak, College Station.

Utah: Vasco M. Tanner, Provo; George I. Reeves, Salt Lake City.

California: John M. Miller, Berkeley.

Oregon: F. C. Keen, Portland.

Wyoming: Ned A. Avery, Laramie; Margaret Greenwald, Powell; John W. Scott, Laramie; Walter F. Congdon, Powell; C. L. Corkins, Powell.

Massachusetts: P. J. Darlington, Cambridge.

Honolulu, T. H.: M. K. Riley.

During the week, 12 sessions were held for papers and discussions or for pictures and talks of an entertaining nature. The first two days were given over entirely to a discussion of forest entomology. This was participated in by forest and general entomologists, U. S. Forest Service and National Park Service workers.

The first session was devoted to a rather general review of the problems and work. This was handled by F. C. Craighead, representing the Bureau of Entomology and Plant Quarantine, U. S. Department of Agriculture, Washington, D. C.; George R. Hopping, Vernon, B. C., representing the Division of Entomology, Department of Agriculture, Canada; F. W. Childs of the U. S. Park Service; Otto Krueger of the U. S. Forest Service; and the following representatives of the U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine forest insect laboratories: John M. Miller, Berkeley, Calif.; James C. Evenden, Coeur d'Alene, Idaho; F. C. Keen, Portland, Ore., and J. A. Beal, Fort Collins, Colo.

Following this general survey of the field one session was devoted to reports of research work, another to control methods, programs and results, and one to a discussion of the type of entomological training best suited for the forester and the forest entomologist.

The Research Program
- Forest Insect Survey of Canada, Objects and Methods—George R. Hopping
- Research at the Berkeley, Calif., Station—John M. Miller
- Nicotine-Sulfate in Bark Beetle Control and the Use of Copper Sulfate to Cure Trees on the Stump—A. S. West, Jr.
- Research Work at the Portland, Ore., Station—F. C. Keen
- Research at the Coeur d'Alene, Idaho, Station—James C. Evenden
- The Problems and Work of the Fort Collins, Colo., Station—J. A. Beal
- The Bark Beetles—Donald DeLeon
- The Effects of Low Temperatures on the Bark Beetle—N. D. Wygant
- The Pandora Moth—J. A. Beal
- Forest Insect Research in the Eastern United States—F. C. Craighead

Control Symposium
- Bark Beetle Surveys—F. C. Keen
- Bark Beetle Control in White Pines—James C. Evenden
- Insect Control Programs in the National Parks—F. W. Childs
- Insect Control as a Forest Service Program—Theodore Krueger
- Surveys and Control in the Pikes Peak National Forest—George H. Brown
- Work in the Medicine Bow National Forest—Ned A. Avery
- The Program in the Roosevelt National Forest—C. K. Collins

The following motion pictures were shown: "The Hemlock Looper," "Forest Dusting by Airplane," "The Western Pine Beetle" and "Bark Beetle Control in the Denver Mountain Parks."

The symposium on "Entomological Training for Foresters and Forest Entomologists" was opened by

F. C. Craighead, George R. Hopping, C. K. Collins, George H. Brown, F. W. Childs and J. A. Beal, with almost everyone in attendance entering into the 2-hour "free for all."

The following subjects were presented during the days following the forest insects symposium:

The Cedar Scale—George A. Dean
Aphids on Conifers—Miriam A. Palmer
Hawaiian Insect Problems—M. K. Riley
A New Household Pest for Colorado—C. R. Jones
Methyl Bromide Fumigation—R. T. Cotton
Insects Affecting Alfalfa Seed Production—Loyd L. Stitt
Grasshoppers (slides and movies)—Sam C. McCampbell
The Long-Winged Grasshopper of the Plains—L. G. Davis
Grasshoppers and Altitude—Gordon Alexander
Grasshopper Egg Identification—R. C. Smith
Grasshoppers in Kansas in 1939—E. G. Kelly
The Grasshopper Situation in Oklahoma—C. F. Stiles
A Survey of the Grasshopper Problem in the Argentine—C. H. Richardson
Grasshopper Bait Tests—C. H. Richardson
Entomological Meetings—M. P. Jones
Tomato Fruit Worm Control—J. L. Hoerner
Wild Life Problems—J. W. Scott
Entomological Examinations—R. C. Smith

Some of the principal features of the evening programs were: Pictures of Hawaii by M. K. Riley; geology of the Rocky Mountain region, P. G. Worcester; the flight of insects (pictures), L. E. Chadwick; pictures from the Argentine, C. H. Richardson; wild life pictures in Wyoming, J. W. Scott; pictures of the 1938 Rocky Mountain Conference of Entomologists, V. M. Tanner; scenic pictures and sunsets of Utah, George I. Reeves.

Following one lunch period John and Frank Craighead, twin sons of Dr. and Mrs. F. C. Craighead, gave lectures on falcon training and flying and demonstrated with one of their trained birds.

The officers elected for 1940 are C. P. Gillette, Honorary Chairman; R. H. Painter, Chairman; George F. Knowlton, Vice Chairman; George M. List, Secretary, and C. R. Jones, Treasurer.

It was decided to make the subject of taxonomy the principal theme of the 1940 Conference.

GEORGE M. LIST, *Secretary*

COTTON STATES BRANCH FIFTEENTH ANNUAL MEETING

The fifteenth annual meeting of the Cotton States Branch of the American Association of Economic Entomologists will be held in Birmingham, Ala., February 7–9, 1940. The Tutwiler Hotel has been selected for convention headquarters and is also headquarters for the Association of Southern Agricultural Workers.

The local committee in charge of arrangements consists of J. M. Robinson, Chairman, H. C. Young, F. E. Guyton and L. L. English.

RESIGNATION OF JOSEPH B. MOORE

Dr. Joseph B. Moore has resigned his position as Entomologist with Washington State Experiment Station to accept a position on the research staff of McLaughlin Gormley King Co., Minneapolis, Minn.

Dr. Moore received his training and degree from Cornell University and for several years was a member of the staff of New York State Experiment Station, Geneva. He will be stationed at Wenatchee, Wash., where he will be in charge of the company's research on codling moth and mite control.

RECENT DEATHS

Dr. L. O. Ellisor, Assistant Entomologist, Louisiana Agricultural Experiment Station, University, La., died October 21, 1939.

Dr. Royal N. Chapman, Dean of the Graduate School, University of Minnesota, died of pneumonia December 2, 1939. Dean Chapman was, at the time of his appointment to the graduate school, Director of the Experiment Station of the Pineapple Producers Cooperative Association, Ltd., of Honolulu, Hawaii. At one time he headed the division of entomology and economic zoology at University Farm, St. Paul, Minn.

C. N. Ainslie, who before his retirement was with the Bureau of Entomology and Plant Quarantine, U. S. Department of Agriculture, died December 5, 1939, at Sioux City, Iowa.

KELLOGG AGAIN IN THE UNITED STATES

Claude R. Kellogg, for the past 2 years at Fukien Christian University, Foochow, China, is again in the United States and located in Pasadena, Calif.

PEST CONTROL OPERATORS CONFERENCE

The fourth annual Pest Control Operators Conference will be held at West Lafayette, Ind., January 15–19, 1940. Advance programs may be obtained from Professor J. J. Davis, Purdue University, West Lafayette, Ind.

NORTH CENTRAL ENTOMOLOGISTS MEETING

Purdue University, West Lafayette, Ind., will act as host to the North Central States Entomologists Conference, March 21–22, 1940.

INSECTICIDE AND DISINFECTANT MANUFACTURERS

The twenty-fifth annual meeting of the National Association of Insecticide and Disinfectant Manufacturers was held in Washington, D. C., December 4–5.

NEW ENTOMOLOGICAL LABORATORY

The Tobacco By-Products and Chemical Corporation, Louisville, Ky., is constructing a modern entomological laboratory, reports Dr. John F. Alsterlund, member of the corporation's research staff. Dr. Alsterlund recently visited staff members of the Illinois Natural History Survey, Urbana. He was with the Illinois research organization before joining the staff of the Kentucky corporation.

EASTERN BRANCH MEETING

The Eastern Branch of the American Association of Economic Entomologists met in New York, N. Y. November 16–17.

Clyde C. Hamilton acted as Chairman. Attendance was in excess of 200.

Thirty-six papers were read or presented by title.

"We had a very good meeting," reports a member of the Eastern Branch who was present.

HORTICULTURAL INSPECTION NOTES

DISCOVERY of additional infestations of the Mexican fruitfly in Texas led the U. S. Department of Agriculture to extend the quarantine regulations relating to the pest to include the counties of Dimmit, La Salle and Webb, Tex. The new regulations became effective October 16. The regulated area now includes six counties and part of another, all in southern Texas. The harvesting season for host fruits of the fly as specified under current quarantine regulations remains the same as heretofore—from September through April of each year—except that, in the three newly regulated counties, the harvesting season for grapefruit ends with the last of February. A host-free period must be observed in all the regulated area throughout the remainder of the year. These local control measures are provided under Texas state regulations.

UNDER an amendment effective September 11, 1939, to the federal quarantine relating to Dutch elm disease, areas in Litchfield and New Haven counties, Conn., in Columbia and Ulster counties, N. Y., and the entire county of Dutchess in New York were brought under regulation for the first time, and extensions were made to the area under regulation in one county in Connecticut, two in New York and five in New Jersey.

RESTRICTIONS on the movement of fruits and vegetables under the Japanese beetle quarantine regulations were removed for the season, effective September 20, nearly 4 weeks earlier than is provided in the regulations. The active period of the beetle was apparently over prior to this date throughout the regulated area. The restrictions on the movement of cut flowers remained in full force until October 15, as provided in the regulations.

OWING to the recent discovery of the pink bollworm of cotton in okra, the regulations of federal quarantine no. 52 were amended in September to require the certification of okra when moved interstate from the regulated areas in Arizona, New Mexico and Texas. Nine additional Texas counties were brought within the regulated area under two amendments to the quarantine made effective in September.

THE Crop Pest Act of West Virginia was amended in 1939, and regulations thereunder were adopted on July 1. The pest control work in West Virginia deals with "(1) the control by compulsory community action of pests published by the Commissioner as dangerously destructive, (2) the eradication of cedars in the vicinity of orchards in counties petitioning for such work, (3) the inspecting and registering of nurseries, and (4) the issuance of quarantines against specific pests whenever the interests of the state require such action." The permit system for out-of-state nurserymen is continued under current regulations, and nursery stock is defined to include the following plants "when produced or improved by any method of cultivation": trees; shrubs; berry plants; fruit trees, wild or cultivated; evergreens, including rooted Christmas trees; and any plant of the above groups not native to West Virginia, whether wild or cultivated.

"A CIRCULAR of general information for those concerned with the movement of agricultural seed into and within the state of California," published by the Bureau of Entomology and Plant Quarantine of that state, deals with the provisions of the Agricultural Code and sets forth the policy, by county, as to disposition of infested crop seed.

A REVISION of the regulations issued by the Alabama Department of Agriculture and Industries on October 20, 1939, with reference to the sale of seed Irish potatoes, provides that all non-certified seed potatoes entering the state "must *NOT have tags attached with any statement thereon reading or implying that the seed potatoes contained therein are of superior quality, personally certified, registered or selected.*"

COMMISSIONERS of the Porto Rican Department of Agriculture and Commerce, in recognition of the possibility of there becoming established a new business in plant material from foreign counties, especially lily bulbs from Japan, issued a quarantine (no. 14) on August 14, 1939, providing for the use of soil as packing material when meeting the requirements of the Bureau of Entomology and Plant Quarantine as given in circular B.E.P.Q. 369, issued February 27, 1939, and when such shipment has been released by that Bureau from the United States as a domestic shipment.

THE COLORADO quarantine relating to the tomato pinworm was revoked October 10, 1939, inasmuch as present knowledge of factors necessary for establishment of the pest indicates, the announcement states, that "under certain conditions, host fruits and plants and parts thereof of tomatoes may be permitted entry without risk of the spread of the injurious insect pest."

A REVISION of California quarantine proclamation no. 6, which became effective August 25, 1939, permits vetch seed to enter California either under certification from clean areas or under prescribed treatment. The states of Oregon and Washington are added to the area as infested under this proclamation.

THE CALIFORNIA quarantine proclamation (no. 13) pertaining to ozonium root rot, as revised effective October 19, 1939, reduces the infected area in New Mexico to eight counties, and adds Washington County, Utah, to the infested area. Intrastate quarantines are maintained by these states.

Errata, Volume 32

Bottom page 134, "Control of Flatheaded Apple Tree Borer in Oklahoma," first 22 lines of column 1 and first 18 lines of column 2, should follow line 3, column 1, page 136.

Page 552, column 2, line 23 should read as follows: Broomsedge, *Andropogon virginicus*

Page 552, column 2, line 49 should read as follows: cucumber beetles rested on the bare soil

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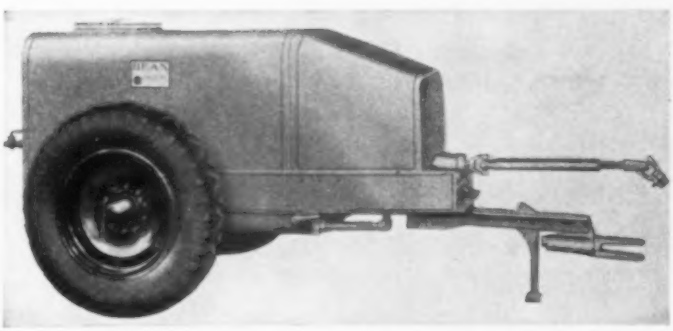

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